INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

Volume 84 — **New York, October, 1926** — *Number 10*

Trends and New Practices in

Use of Power Drive Equipment

which includes a discussion of some outstanding developments in the design and application of devices employed to connect the motor to its load

By **FRANK E. GOODING**
Associate Editor, Industrial Engineer

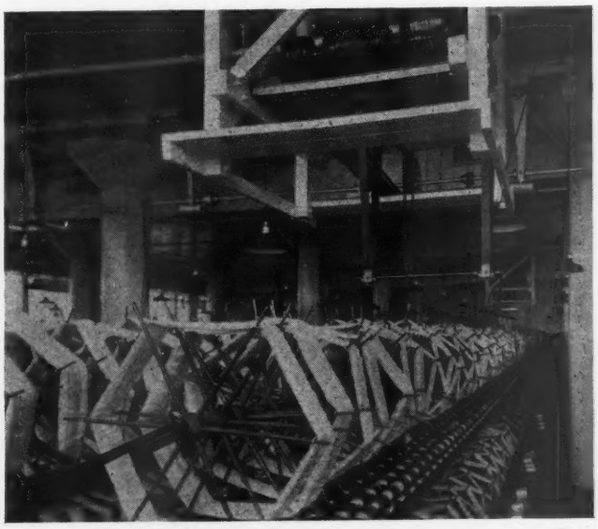
BEFORE the advent of the electric motor into industry and for some time afterward practically all machinery was driven from lineshafts which, in turn were connected to steam engines or waterwheels by belts or ropes. As large engines were more economical, the size of these lineshafts was increased both in length and in diameter until it was not uncommon to use shafts from 4 to 6 in. and even larger in diameter, and often over 200 ft. long. Frequently, the lineshafts on several floors of a mill or factory were driven by a single engine through a complicated connection of mainshafts, jackshaft and clutches.

Large shafts require large bearings and heavy belts which, in turn, necessitated heavy pillow blocks, floor stands or hangers. Also, it was the general practice to step down the diameter of the shaft with the increase of the distance from the driving pulleys or sheave, which resulted in a nightmare of sizes of shafts and bearings, and pulleys with a wide variety of bores. The advent of the split pulley with adjustable bushings solved the pulley problem to a certain extent. The industrial period just described was one of complete mechanical drive.

In those days when the entire transmission line was practically a single inter-connected unit, or at least entirely dependent upon the central main driveshaft, a bearing failure in an important location would often shut down the entire plant. One of the main requisites of the Master Merchanic or Millwright in charge of the transmission line was the ability to "nurse" a hot bearing until quitting time. Each man had his own remedy, such as salt water, beer, and many "mysterious" concoctions of which he alone knew the recipe. When a bearing became dangerously warm, a man was stationed at it to flood it with his favorite cooling solution. Scientific lubrication and a knowledge of methods of reducing friction were unknown.

With the perfection of electric motors many of these engines were scrapped or connected to generators, and the motors belted up to lineshafts which, in many cases, were merely sections of the old shaft. As a result, many of these shafts were larger than necessary and had heavy friction losses in old bearings. Because it was easier to measure the power used by a motor than by an engine, industrial operating men began to study the load on the motor both with and without the machine load. It was in this way that the heavy friction loss of the old-type, oversize lineshaft, operating in plain bearings, was discovered.

Some industrial men became convinced that the way to eliminate this friction loss was to take out all the shafting and bearings and connect the motor to the individual machine. Several textile mills where, in addition to the friction loss, oil dripping from overhead bearings caused considerable damage to the product, made installations in which each machine had its individual motor. These installations were described in the technical press and discussed extensively in engineering gatherings. As a result, about 10 or 15 years ago, industry in general be-



This JFS variable-speed transmission is installed in a Midwestern silk mill.

This is a new type of variable-speed transmission, the construction of which is explained and illustrated on page 495. The crank, which is mounted below the platform, operates the sprocket speed-changing wheel on the unit by means of the chain. In textile mill work, the variable-speed transmission is of special advantage in obtaining the proper speed for any condition of humidity, quality, or size of product.

gan to take a decided trend toward individual motor drive. That may be called a period of electric drives.

In some cases, individual drive was installed because other plants were making the change and without any careful analysis as to whether it was the most advantageous or economical. The high cost of making the change was probably the greatest deterrent to more widespread adoption of individual drive. New installations in many lines of industry were quite generally made with individual drive.

Within the past few years industrial operating men have begun to study and analyze their power transmission problems. The electric motor is becoming generally accepted as the logical and most economical driving unit. One man interviewed believes, however, that the steam engine will return as the driving unit in certain industries, such as in paper manufacture, where low-pressure steam is used in the process. Nevertheless, few industries dispute the advantage of the motor. The question now is, How can it be used to the best advantage?

Several of these factors which are responsible for the new attitude toward the method of applying the motor to its load are mentioned here and will be discussed more fully later in the article. For example, the increasing use of ball and roller bearings on lineshafts has decreased the friction loss and removed this objection to lineshaft drives. Wide publication of the investigations of The Leather Belting Exchange in their research work has shown industry the best methods of using leather belt, and pointed out its advantages and economy. Also, tests made under the supervision of this Exchange have indicated to the belt manufacturer methods whereby he has improved his product. Manufacturers of fabric base and rubber belts have likewise improved their product. Also, the series of articles by Robert W. Drake, Electrical Engineer, McCormick Works, International Harvester Company, Chicago, Ill., entitled, "When to Use Group and Individual Drive," which appeared in the February, March, and April, 1924, issues of INDUSTRIAL ENGINEER, and of which upwards of 70,000 reprints were distributed in industry, have set industrial men to thinking that the decision on whether group or individual drive should be installed should be based upon an analysis of the drive and the problems connected with it. In addition, during the past several years, there have been added a number of mechanical devices, such as silent chains, clutches, flexible couplings, speed reducers, variable-speed transmissions, silent gears, short-center belt drives, and other devices for connecting the motor to its load. Added types or improvement to a number of these have been announced within the past year. All of these factors have tended to make both group and individual drive more reliable. Practically every application of a motor to its machine now has pulleys, a belt, lineshaft, sprockets, chains, gears, flexible couplings, speed reducers, or other mechanical elements introduced between the motor and its load.

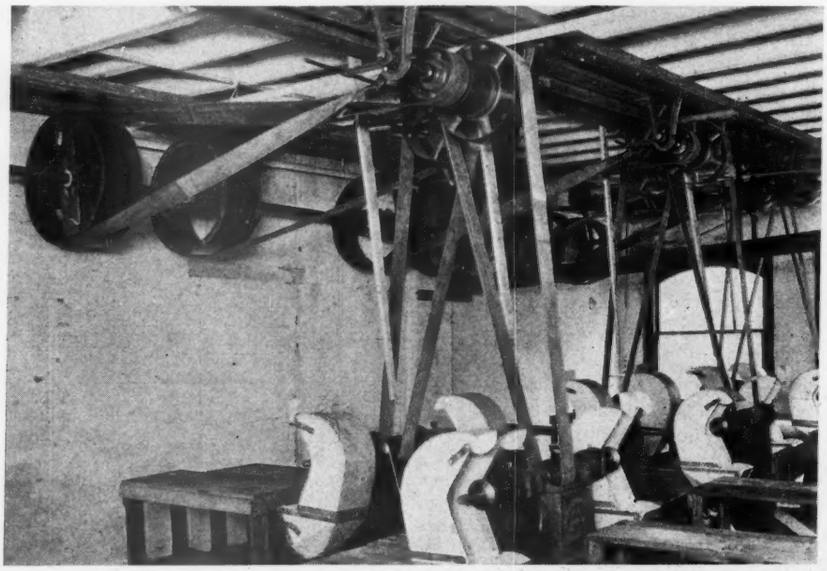
When operating executives consider the extent of the use of power in industry, they will appreciate the importance and large total saving which could be made through a small economy in the use of power. It has been estimated through recent surveys that industrial plants are now using about 23,552,665 horsepower, which is applied through some 1,936,-114 motors. The types of drive used in connection with these motors are divided approximately as follows: belts, 990,312; chains, 101,181; and direct, that is, through couplings, gears, speed reducers, and so on, 835,699. The trend of future analysis will be watched with considerable interest by industrial men.

The present trends in power transmission will be discussed under the various sub-headings of the different auxiliary equipment used in connecting the motor to its load.

Group or Individual Drives—As stated before, the day of the long, heavy lineshaft is past. Also, there seems to be a more general tendency not to go to the extreme and make a whole plant individually driven, which results in a better balance between group and individual drives, according to the use or service conditions surrounding the installation. For example, in the woodworking department of plants, machines are commonly individually motorized. Some of the reasons for this are that woodworking machines are operated at high speed (often a frequency changer is used to increase the motor speed) and so the motor can be connected directly to the shaft of the machine, or with comparatively little increase or reduction of speed through a belt or other type of transmission. Also, the machines are usually widely separated to give floor storage space and seldom positioned in a line. In addition, one or more machines may be idle for a considerable period. All of these reasons favor the individual motor-driven unit.

On the other hand, where machines are alike and operate as a group and in a straight line and where the majority or none are operating at any one time, as in a battery of screw machines, lathes, milling machines, and so on, group drive through a lineshaft has economical operating advantages which should be considered. Some of these advantages

In this plating plant the buffing heads are driven from a Daggett ball-bearing, loose-pulley countershaft.



This is a typical example of a machine shop with individual drive.
This illustration was taken in one of the plants of the Westinghouse Electric & Mfg. Co.

are: The horsepower rating of the single motor on the group is much less, commonly ½ to ⅓ of the total corresponding rating of the motors on individually-driven machines, which gives more economical operation of the motor and a lower installation cost. Also, the machines are grouped and the lineshaft can be short, usually.

Where production layout demands that machines in small groups be placed out of line as in the so-called "unit production" plan in automobile plants, it is not always feasible to use a lineshaft. Also, flexibility of operation is of great importance in such cases and so individual drives are often used.

It is easily appreciated that any discussion of the type of drive on each machine or group of machines is an individual problem which should be determined by a study of the operating conditions, such as: relation to other machines, continuous or intermittent operation, relation of starting load to running load, operating flexibility required, original and operating cost, probable maintenance requirements, and other factors, which cannot be taken up at length in this article.

Lineshafts—In group drives instead of placing as many machines as possible in a single large group, the more general practice today is to subdivide these machines into numerous small groups of approximately uniform size. In different plants visited during the past year, it was the practice to standardize for each group the size of the motor, the lineshaft diameter and speed, and, as nearly as possible, belt widths and pulley sizes. The standard sizes adopted for the motors for each group varied with the operating conditions in these plants. In a few plants handling light work and using comparatively small machines, the groups were standardized to 15-hp. motors and in others to 20-hp. motors. Motor standards of 25 hp. and 35 hp. were used in other plants with heavier machines. One large plant with a wide variation of light and heavy work had three standard size groups driven by 25-, 50-, and 75-hp. motors, respectively.

Standardizing of the group size and speed requires fewer spare motors. Speed is standardized by making all driving pulleys on the shaft of the same diameter and putting on each motor a pulley which will give the proper reduction. Whenever a motor is changed the belt will fit on the new one because these pulleys are standardized. The men in each shop visited took pride in stating how quickly they could change a motor.

One Midwestern mill supply house reports that practically all the lineshafting sold is either 2 1/16, 2 3/16, 2 5/16, or 2 7/16 in. in diameter, which is a fair indication of the comparatively small size of the group drive today. Some shafting below 2 in. in diameter is sold to the tailor shops and other light manufacturing plants. Comparatively little call is made for shafting over 3 in. in diameter and this is largely for replacement or addition to existing lines.

With the increasing use of ball, roller and tapered-roller bearings for lineshafts, the compression type of coupling is becoming more generally used than flange couplings. This is because compression couplings are much more easily removed when it is necessary to slip bearings on or off over the end of the shaft.

Many new industrial plants are simplifying the problems that are incidental to the erection and shifting of lineshafts by the use of special steel shapes for supporting the shaft. These shapes of the Midwest (Midwest Steel & Supply Co.) type are inserted in the forms in concrete buildings before the concrete is poured and the stringers, which are also of special steel shapes, are attached to these inserts. When a building is constructed these inserts are placed at convenient distances apart throughout the entire ceiling so that a lineshaft may be easily erected anywhere. Because of changes in production demands the machinery and the shafting are shifted frequently in many plants and such construction simplifies making the change. The use of special steel shapes is not confined to concrete buildings and to new construction, however. In many old steel frame or mill-type industrial buildings these shapes are also used as stringers and footings. Because wood is less expensive in first cost and is universally accessible, it is perhaps more widely used for supporting shafting, however.

Industrial men are beginning to realize more clearly the importance of substantial supports for the lineshaft as well as the proper alignment and frequent re-alignment. Departments which have this work to do are keeping their forces employed steadily on general plant maintenance work so that they have better trained men for these jobs when called upon to shift machinery or a shaft on short notice. Trouble in many cases is no doubt attributable to the use of low-grade workmen in the erection and installation of the shafts and bearings.

Bearings—One of the most important steps toward the modernization of lineshaft drives has been the development of special hanger boxes with ball, roller, or tapered-roller bearings for use on lineshafts. These are of two general types: one in which the hanger box and hangers are specially built as a unit, and another, commonly known as the dumb-bell type, which is now available with any of the three types of bearings. This dumb-bell type is made to fit the various standard types of hangers and replaces the old hanger box. Some of the well-known types of so-called anti-friction bearings which have been put into hanger

Screw machines are a type of equipment which is well adapted to group drives.

In this case a battery of screw machines at the Addressograph Co., Chicago, Ill., is operated from a group drive. The mainshaft is driven by a motor through a Link-Belt silent chain. The lineshaft bearings are all Dodge-Timken.

boxes for power transmission work are: Chapman, Daggett, Dodge-Timken, Hyatt, Woods-Fafnir, and SKF. Some of these have been on the market for a number of years and have well demonstrated the advantages claimed for such use of anti-friction bearings. Others have been announced within the past year or two and additional lineshaft bearings are under process of development.

Manufacturers of these bearings have issued statements of tests which indicate a large saving in friction loss through their use. Another important advantage, in addition to the reduction of the friction loss, is that they need infrequent lubricating attention in contrast to the older type of bearing which required attention every day, or oftener, and in many cases failed or caused trouble through neglect for a short time only. These bearings require attention approximately only from one to four times a year, depending upon the service conditions. It is stated that in general these bearings suffer more from over-lubrication than from under lubrication. This is especially true where the lubricant, particularly grease, is forced in and the bearing filled under pressure. Lubrication problems, however, will be discussed later in this article as well as in the article on page 482.

A large proportion of new installations of lineshafts have bearings of the anti-friction type. In many other cases, plants are gradually modernizing their lineshafts by replacing their old bearings with the newer type whenever the old bearings cause trouble, or when the shaft is shifted to a new location. One large manufacturing plant in Chicago has followed this practice of replacing all troublesome bearings with new anti-friction bearings and discarding all old bearings on the entire shaft whenever it is moved, until practically the entire plant, containing several thousand bearings, is so equipped. This is a typical example of what is being done in many other industrial plants.

With the use of these anti-friction bearings many plants have speeded up their lineshafts until 500 r.p.m. is not at all uncommon, particularly on grinding or buffing operations. Also, in numerous instances where these bearings are used, the motor has been connected on to the end of the lineshaft through a flexible coupling and is operated at the motor speed, which in one case was 1,150 r.p.m.

The installation of these new bearings has emphasized to industrial men, the importance of correct alignment. A representative of one of these bearing companies states that in many instances when he calls at an industrial plant to supervise the installation of the new bearings, no one in the plant remembers when the shaft alignment was checked last. The new installation gives an opportunity to call attention to the necessity of alignment, so that many industrial plants are now making regular provision for such checks. For example, one Ohio plant checks the alignment of all shafts during the two weeks' shutdown period each summer. Other plants check up alignment at 2-year intervals.

Bearing trouble is probably the most common cause of plant stoppage, and many improvements have been made by manufacturers of machines, motors, and other industrial equipment, either by the adoption of anti-friction bearings or through the improvement of the existing bearings and better provision for their lubrication. Many interesting experiences with the use of such bearings in motors, particularly on cranes, have been reported in previous issues of INDUSTRIAL ENGINEER. This reduction of friction, both in the motor and on all rotating parts of the driven machine, has done much to improve the efficiency of power drives.

An unusual type of bearing, brought out within the past few years, is the Goodrich cutless rubber bearing, which is designed for use under water, particularly in paper mills.

Belts—Considerable work has been done by The Leather Belting Exchange through its research activities and educational work among the users of leather belts on the use of belts, how to take care of them, operating considerations, and other factors. One of the important results of these campaigns has been the wider use of cemented endless belts in industry. A large number of factories have adopted the practice of making all leather drive belts over 6 in. in width endless. This has been a very important factor in obtaining smooth power transmission. Although fasteners work satisfactorily, if put on properly, in many cases, too little attention has been given to their installation. Cementing a belt is a longer and somewhat more difficult job and requires greater attention. Also, the belt is held in position on the pulleys while it is cemented. This tends to hold it in the proper position and alignment. Smaller leather belts are commonly fastened by means of Alligator, Clipper, Detroit, or some of the other types of flexible lacings in which a metallic hinge is placed in the end of each belt and the two ends connected with a pin. A millwrighting contractor recently stated that during the past year he had been required in only one instance to use rawhide belt lacings and these were on hand-shifted belt drives, over step-cone pulleys. One of the important reasons for the popularity of the metallic lacings is the ease and

quickness with which they may be applied. Another practice in belt drive which has caused considerable argument among old-time industrial men has been whether the grain or flesh side of the belt should run next to the pulley. Tests have shown that the grain side transmits considerably more power, particularly as soon as the belt is broken in.

One place where practically every industrial plant still has an opportunity to modernize its application of the belt drive in the transmission of power is by the use of higher belt speeds. Many plants are operating belts at speeds not over 2,500 f.p.m., whereas they could be operated much more efficiently at 3,500 to 4,000, or even 4,500 f.p.m. Tests made by The Leather Belting Exchange have shown that the maximum operating speed of a leather belt is approximately 8,000 f.p.m. Increasing the belt speed is one of the easiest and simplest methods of getting more out of the belt drive. This is well recognized by many industrial men who solve many of their belt drive problems by increasing the pulley diameters, while maintaining the same ratios, and so increase the belt speed. Since horsepower is a factor of speed and tension, the belt at the new speed will easily pull a load which, under former speed conditions, was virtually an overload. Leather belts are receiving much more care today in industrial plants and are being cleaned, degreased, recemented, and in many cases rebuilt within the industrial plant. In this way, their life is almost doubled.

Due to the increased cost of floor space, or increased demands for space in industrial plant, considerable attention has been given to the use of short-center or gravity-idler belt drives, such as the Belt Slacker, Lenix and Pulmax drives, U. G. Automatic Belt Contactor, Medart Belt Adjuster, and others. These drives wrap the belt on the driving pulley and so increase the arc of contact with a short belt, whereas under the old practice, it was always necessary to have a long center distance between pulleys with high reduction ratio. These short-center belt drives necessitate using cemented endless belts and some belt manufacturers, on account of the reverse bending of the belt under the gravity idler, have recently developed especially pliable belts for such use.

Rubber and fabric-base belts have a wide use, particularly under certain operating conditions. For example, rubber belts are commonly used for very wet service conditions. Industrial men are realizing that a great deal of attention must be given to the joining of rubber and fabric-base belts. There are a large number of plates, hooks, clamps, and other connectors which are used for this purpose.

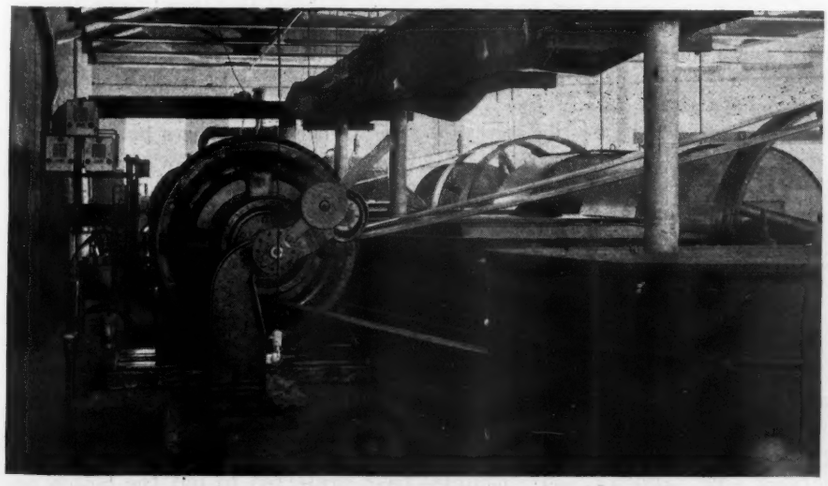
Considerable experimental work has been done, and several installations have been made, using steel belts for transmitting power. These, however, are not used extensively.

A comparatively recent development is the Texrope (Allis-Chalmers Mfg. Co.) drive which consists of fabric base belts of triangular cross-section which fit into V-grooves on the driving and driven pulleys. A considerable number of these drives are being tried out in various industries and the experience with them is being watched with a great deal of interest. A Texrope drive installation is shown in an accompanying illustration.

Chains—It has been estimated through an industrial survey that about 5 per cent of the motors in industrial plants are connected to the load with chain drives. The use of a chain to connect the motor to its lineshaft is very common because this gives a short-center drive with a positive speed reduction ratio. A recently installed lineshaft drive of this type is shown in an accompanying illustration. One of the reasons for the widespread use of chain drives is their adaptability through a wide range of horsepower and speed ratings. Users are becoming more accustomed to taking into account the service conditions and consulting the manufacturer when considering a chain drive. Excessive and repeated overloading (particularly if a shock load) causes a mechanical strain on the elements of the chain, which, if continued, will have its effect. With chain drives and all other elements of power transmission equipment, it is necessary to use service factors in determining the size or rating of the mechanical unit in order to compensate for unsual operating conditions. The use of roller chain for power transmission, particularly in drives, is increasing.

With chain drives and other positive connections of a motor to its load, it is frequently necessary to provide a safety link so that in case the machine is stopped suddenly, the link will break before some more expensive part of the equipment breaks. These breaking links, or safety links, are usually fitted into the sprockets of silent chains. This link serves as a mechanical fuse to protect the equipment the same as the electrical fuse protects the motor. Industrial men who have tried to develop these safety links in other types of drives and in machine mechanisms are strong believers in the advantages and decreased maintenance accruing from them.

Silent chains up to 10 hp. are being stocked to some extent in distributing centers over the United States so that immediate delivery may be obtained. These are kept in stock only in certain reduction ratios which give the more commonly used operat-



Gravity idlers are frequently used to maintain the proper tension on belts, particularly where there is considerable difference in the diameters of the driving and driven pulleys.

In this instance, a 150-hp. 435-r.p.m. slip-ring motor with extended shaft is used in connection with Lenix drives to operate beaters in pairs in a paper mill. Lenix and other types of short-center drives save considerable floor space in the modernization of industrial plants.

ing speeds when connected with standard speed motors.

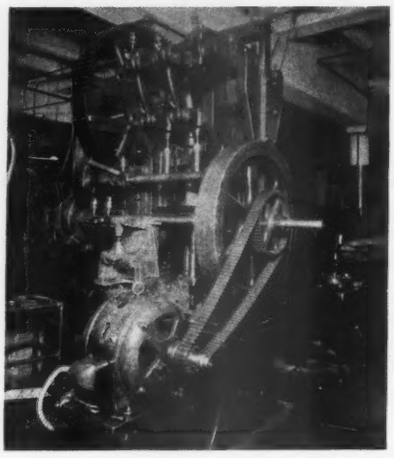
Gears—Open-gear drives have always presented one of the troublesome lubricating and operating problems in industrial plants. Many of these have been supplanted with silent chain because the latter give a positive reduction ratio. However, the tendency, wherever it is desirable to use gears, is to enclose them and if possible provide for a bath or splash system of lubrication.

Much use is being made of the so-called silent or non-metallic gear, particularly those made of Bakelite composition and marketed under various trade names, such as Fibroc, Formica, Micarta, Textolite, Fabroil, and so on. Gears of these materials have done much to reduce wear and prevent the noise which have always been considered as unavoidable with gear drives. During the past year a special Fibroc gear material has been placed on the market which is impregnated with graphite, to give it, according to the manufacturer, self-lubricating qualities.

Speed Reducers—Due to the increase in operating economy of the high-speed induction motor, which operates at a speed several times that used for the driving shaft of many machines, it was necessary to provide some means of obtaining the large reduction in speed in a closely-coupled drive. For a considerable number of years both the worm and gear types of speed reducers have been gaining the attention of industrial users. These reducers can be used either singly or in combination to make extremely high reduction ratios.

Some of the types of gear reducers are made in ratings up to 250 hp., although other manufacturers set 100 or 150 hp. as their maximum size. Two types of gear reducers, the Lipe and the Albaugh-Dover are provided with anti-friction bearings. Also, several manufacturers have redesigned their worm gears to provide them with ball or roller and also improved plain bearings. In some other cases the angle of the worm and the material of which it is made has been improved. A double-reduction worm gear has been brought out comparatively recently by the DeLaval Steam Turbine Co., which enables a much higher reduction ratio to be obtained through worm gearing. In this reduction unit, special oil-circulating and lubricating features are incorporated. Additional information regarding reducers will be given in the accompanying article beginning on page 474.

During recent years considerable attention has been given to the herringbone speed reduction unit, and there is a great deal of competition in the application of this type, particularly from 50 hp. and up to the capacity of the planetary, and non-planetary spur gear reduction units. Herringbone gear units are made in single- and double-reduction units and are coming into very common use in large sizes for transmitting upwards of several thousand horsepower, as in steel mill drives, and are used almost altogether above 150 to 250 hp.



On some machines, particularly where a motor of more than 5-hp. rating is required, individual drive often affords important operating advantages.

Operating men are carefully studying the power transmission problems in connection with their machines to determine the best type of drive for each. This Bliss punch press is connected to the motor by a 10-hp. Link-Belt silent chain. Press drives, because of the shock load, require special attention to the rating of the drive.

Although users of speed reducers are becoming much more familiar with them and with the requirements of their specification, however, in many cases the user neglects to consider that the amount of power to be transmitted at the low speed is the most important factor in the determination of the proper size of reducer. Also, that unusually severe service conditions necessitate the use of a service factor in determining the rating of the unit.

Flexible Couplings—Another important mechanical element of power transmission equipment is the flexible coupling particularly for high-speed operation. There is a wide range of types and kinds of flexible couplings, many of which were described in articles on flexible couplings in the November, and December, 1923, issues of INDUSTRIAL ENGINEER. The flexible coupling is used on the end of the motor shaft, speed reducer shaft, or other driven units, to connect the shafts and take care of any slight misalignment. For example, while every effort should be made to line up a motor and a speed reducer, centrifugal pump, or other such machines, perfect alignment is seldom obtained, and a very slight misalignment which may be hardly discernible when testing the alignment would cause considerable trouble at high operating speed, if the shafts were connected by a solid coupling. In some cases operating men consider a flexible coupling as a universal joint and do not use sufficient care in the alignment to prevent operating troubles. Through past experience and education many users are becoming more acquainted with the proper application of such units, the necessity of applying service factors when selecting units for particularly severe operating conditions, and the importance of obtaining as near perfect alignment as it is possible to obtain, with foundations or other mountings sufficiently substantial to retain the alignment as long as possible. Operating men are also finding that alignment needs frequent checking.

Some manufacturers are stocking flexible couplings in fractional horsepower sizes and up to 10-hp. rating in mill supply houses and in various distributing centers. Flexible couplings are manufactured in capacities ranging from fractional horsepower up to several thousand horsepower, for steel mill drives. Special units are made for extremely high speed operation, which requires more perfect balancing of the elements of the couplings, and also for installations where a noticeable lack of alignment is necessary, and is compensated for by double units. A recent development is the use of a special flange built on a coupling on which the circumference is used as a brake wheel. One of these is shown in an accompanying illustration.

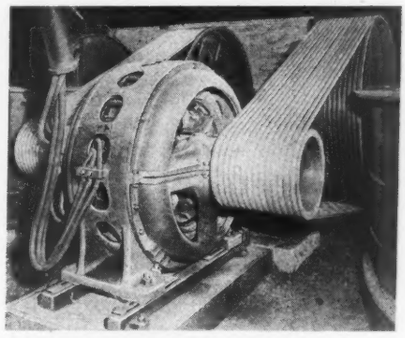
Clutches—A recent development in clutches and cutoff couplings has been brought out by the Edgemont Machine Co., through the addition of anti-friction bearings in the couplings. Many industrial men have a preference toward putting clutches on machines rather than on the line-shafts, although this is not at all universal. Some industrial plants have preferred to put the clutch on

the lineshaft as in that way the countershaft is eliminated. In general, there has not been as much mechanical development on clutches during the past few years as there has been in the case of bearings, flexible couplings, and other equipment. With the modern tendency toward high-speed operation, clutches are subject to very severe operating service.

Variable Speed Transmissions—Variable speed is obtained generally either electrically, mechanically, or hydraulically. Control of variable-speed motors in practically all cases gives the increments in speed in definite steps and seldom gives a minimum speed less than one-half of full speed. In many cases, only a few steps or variations are obtainable. Variable-speed motors were first applied to direct drive on machines and some difficulty resulted in many cases due to neglect to consider that usually the greatest power requirements, as on a lathe for example, were found at the lowest speed, where the motor delivered the least power. This difficulty may be corrected by providing increased motor capacity. Variable mechanical power reduction is obtained either by means of a shifting belt on a pair of cone pulleys as in the Moore & White variable-speed transmission, or through shifting the diameter of a pair of V-faced pulleys driven by a V-belt as in the Reeves and the Lewellen variable-speed transmissions. With these units variation is obtained in very small increments over a considerable range of speed from slightly above to below the input speed.

Recently, the JFS, a new mechanical, variable-speed transformer, which is described in detail in the New Equipment section on page 498 of this issue, has been placed on the market. This is a device which gives a variable speed reduction.

Hydraulic speed reducers, such as the Hele-Shaw (American Engineering Co.), Oilgear (The Oilgear Co.) and the Waterbury (Waterbury Tool Co.) which is also described on page 497 of this issue, consist of a pair of hydraulic pumps, turbines, or motors, so connected that the unit operating at the intake speed delivers a variable amount of liquid, usually oil, to the other unit, which is thus driven at a speed corresponding to the amount of liquid which it receives.

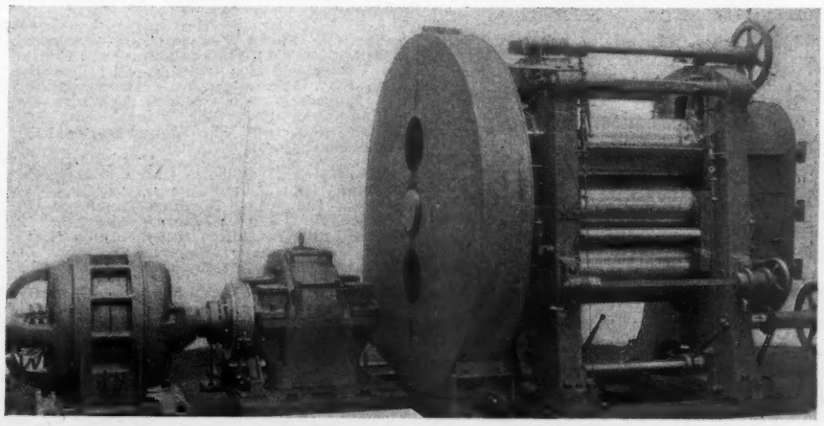


An example of a Texrope drive in a paper mill.

In this case two Texrope drives on 84-in. centers are operated from a 250 hp., 440-r.p.m., type ANY Allis-Chalmers motor to drive two pulp beaters at 122 r.p.m. The Texrope drive is a V-shaped endless, textile base belt made up in individual strands, which fit in grooved pulleys.

Both mechanical and hydraulic variable-speed transmissions permit very slight variations of speed over a considerable range. In addition, the hydraulic units permit a variation from zero, in most cases, up to the input speed in either direction; that is, they are reversible. Variable-speed devices are becoming widely used in textile work where the speed of operation depends upon the weight or grade of material manufactured, conditions of humidity, quality, and other factors. Another new tendency in these units is to use them to start up machines at slow speed and gradually work up to operating speed. This is particularly noticeable in the automobile conveyor assembly lines which are driven slowly at first and the speed gradually increased as the men become "warmed up" to their task and also, in textile mills, where the machines are started slowly to prevent breakage of thread.

Lubrication—No doubt one of the most noticeable steps toward the modernization of power drives is the change in knowledge of, and attitude toward, lubrication. Much of this is due to the widespread use of the automobile and the general realization of and experience with the importance of its lubrication as well as the improvement in lubricants and greater knowledge of their purpose and application, which has been obtained through the study of automobile bearings and lubricants, by the manufacturers of both. Not many years ago it was the practice in many plants to hire a man at the gate and put him to work oiling equipment, with comparatively little instruction or supervision. Today, with anti-friction and other improved bearings, lubrication receives much less frequent but more careful attention. This new attitude is well illustrated by the practice of the management of a Michigan factory manufacturing forgings. In this plant, an experienced mechanic, at corresponding wages, does all of the oiling, even to the machines, and the management considers the difference in wages above what is commonly paid an oiler as well spent because of the very noticeable decrease in bearing troubles and maintenance cost, in addition to the saving in lubricants and freedom from interruptions. Industrial men are learning that the selection of the proper lubricant and its application are of the utmost importance. In the opinion of some industrial engineers improvements in bearings and methods of lubrication, which have been developed together, have been the outstanding features in the bet-



This is an example of the use of a brake coupling on a three-roll calender.

Here one half of the Francke coupling is mounted on the motor shaft in the usual way and the other half is bolted against the brake wheel. This brake wheel is fastened on the end of the pinion shaft of the reduction gear which, in turn, drives a second gear reduction connected to the three-roll calender. This coupling is on a 690-r.p.m., 50-hp. motor.

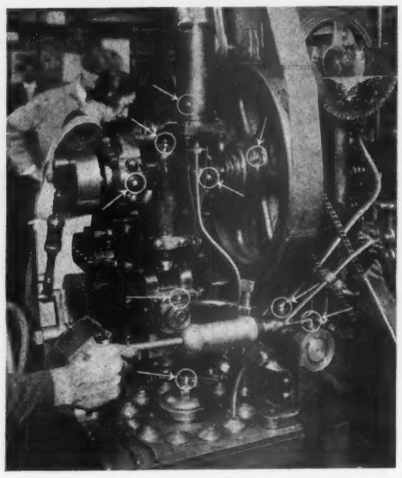
terment and modernization of power transmission equipment. Increased operating speeds have made necessary these improvements in bearings and their lubrication in motors, hanger boxes, and practically all types of machines.

Considerable attention is being given to the application of lubricants by means of the portable pressure lubricating devices such as the Adams, Alemite, Alemite-Zerk and Dot systems, as well as a number of pressure lubricating devices which are built into the machine, such as Bowen, Detroit, Keystone, Madison-Kipp and McCord, which were described in the article entitled, "Equipment Used for Applying Lubricants," on page 213 of the May, 1926, issue of INDUSTRIAL ENGINEER. Some of these lubricating devices are used for oil and others for grease lubrication. Safety to the oiler and the use of pressure, which forces the lubricant into the bearing, are the chief advantages claimed for these types of lubricating devices. Also, where a machine is fitted with any of the positive built-in types of lubricators, all bearings are lubricated simultaneously and none is overlooked. The lubrication of many bearings in industrial plants is a hazardous operation for the oiler and accidents are very likely to be serious. One large industrial plant in Detroit states that it has practically eliminated accidents to the oilers through the introduction of a pressure system of lubrication, whereas previously the hospital contained at all times one or more oilers who had been injured.

Because of the danger of overfilling anti-friction bearings Fairbanks-Morse Co. has brought out a ball-bearing grease for their motors in collapsible, soft-metal tubes of various sizes, each of which contains the correct amount of grease for a special size of bearing.

One of the most difficult lubrication problems in industrial plants is in connection with loose pulleys on mainshafts or countershafts. As a result, many men are using ball-bearing countershafts, such as the Daggett (Chicago Pulley & Shafting Co.), in which the tight and loose pulleys both operate on ball bearings in the hubs of the pulleys because ball bearings are easier to lubricate and require less frequent attention. One Chicago concern, for example, purchases all machines without countershafts and obtains a ball-bearing countershaft separately. On existing installations, the countershafts, as soon as they cause excessive trouble, are replaced.

In the same way, many industrial plants are using the Gast oiling machine (Standard Pressed Steel Co.), which consists of a special oil chamber with a chain oiler that fits over a bushing in the hub of the pulley and supplies the lubricant to the bearing as the shaft revolves.



Modern factory practice gives close attention to lubrication.

In this case the bearings on a special press are fitted for the Alemite-Zerk system of lubrication. The circle shows the fittings on the bearings which are lubricated from the pressure gun in the foreground.

Within the past year the Dodge Mfg. Corp., Mishawaka, Ind., has announced a roller-bearing loose pulley. This consists of a cast-iron or Oneida steel pulley provided with an extra large bore to receive a Dodge-Timken roller bearing.

One of the most noticeable features in connection with power transmission problems in present-day industrial plants is that a great deal of attention is being given by the operating executives to investigating new types of equipment much more thoroughly than formerly, and purchasing them on a quality, reliability, and low-maintenance-cost basis, when plans are being made for the modernization of the power drive equipment.

EDITORS' NOTE. Acknowledgment is made to the following companies for illustrations and information used in the preparation of this article:

General Power Transmission — Bond Foundry & Machine Co., Manheim, Lancaster Co., Pa.; Chicago Pulley & Shafting Co., Chicago, Ill.; Dodge Manufacturing Corp., Mishawaka, Ind.; Falls Clutch & Machinery Co., Cuyahoga Falls, Ohio; The Hill Clutch Machine & Foundry Co., Cleveland, Ohio; Medart Co., St. Louis, Mo.; T. B. Wood's Sons Co., Chambersburg, Pa.

Belts, Belt Drives and Supplies — Alexander Bros., Philadelphia, Pa.; Allis-Chalmers Mfg. Co. (Texrope), Milwaukee, Wis.; Bird Machine Co., Pulmax Drive Division, So. Walpole, Mass.; Birdsboro Steel Foundry & Machine Co. (Jackson Lacer), Birdsboro, Pa.; The Bristol Co. (Steel Lacings), Waterbury, Conn.; Chicago Belting Co., Chicago, Ill.; Chicago Flexible Shafting Co. (Alligator Lacing), Chicago, Ill.; Clipper Belt Lacer Co., Grand Rapids, Mich.; Detroit Belt Lacer Co., Detroit, Mich.; The Diamond Rubber Co., Akron, Ohio; R. & J. Dick Co., Inc., Passaic, N. J.; B. F. Goodrich Rubber Co., Akron, Ohio; Goodyear Tire & Rubber Co., Akron, Ohio; Graton & Knight Mfg. Co., Worcester, Mass.; The Medart Co. (Belt Adjuster), St. Louis, Mo.; Harry M. Perry (Belt Slacker), Los Angeles, Calif.; The Republic Rubber Co., Youngstown, Ohio; J. E. Rhoads & Sons, Wilmington, Del.; Chas. H. Schieren Co., New York, N. Y.; F. L. Smidth & Co. (Lenix Drive), New York, N. Y.; Stanley Belting Corp., Chicago, Ill.; U. S. Rubber Co., New York, N. Y.; Victor Balata & Textile Belting Co., New York, N. Y.; I. B. Williams & Sons, Dover, N. H.

Chain Drives — American High Speed Chain Co., Indianapolis, Ind.; Baldwin Chain & Mfg. Co., Worcester, Mass.; Boston Gear Works Sales Co., Norfolk Downs, Mass.; Chain Belt Co., Milwaukee, Wis.; Diamond Chain & Mfg. Co., Indianapolis, Ind.; Link-Belt Co., Chicago, Ill.; Morse Chain Co., Ithaca, N. Y.; Ramsey Chain Co., Albany, N. Y.; and Whitney Mfg. Co., Hartford, Conn.

Flexible Couplings—The Bartlett Hayward Co., Baltimore, Md.; The Clark Controller Co., Cleveland, Ohio; The Falk Corp., Milwaukee, Wis.; R. D. Nuttall Co., Pittsburgh, Pa.; Poole Engineering Co., Baltimore, Md.; and Smith & Serrell, Newark, N. J.

Hanger Bearings—Chicago Pulley & Shafting Co. (Daggett) Chicago, Ill.; Dodge Manufacturing Corp., Mishawaka, Ind.; The Fafnir Bearing Co., New Britain, Conn.; Hyatt Roller Bearing Co., Newark, N. J.; Timken Roller Bearing Co., Canton, Ohio; The Transmission Ball Bearing Co., Inc. (Chapman) Buffalo, N. Y.; SKF Industries, Inc., New York, N. Y.; and T. B. Wood's Sons Co., Chambersburg, Pa.

Lubrication and Lubricating Devices—Adams Grease Gun Corp., New York, N. Y.; The Bassick Mfg. Co. (Alemite and Alemite-Zerk), Chicago, Ill.; Bowen Products Corp., Auburn Div., Auburn, N. Y.; Carr Fastener Co. (Dot), Cambridge, Mass.; Detroit Lubricator Co., Detroit, Mich.; Gits Bros. Mfg. Co., Chicago, Ill.; Kelly Lubricator Co., Syracuse, N. Y.; Keystone Lubricating Co., Philadelphia, Pa.; Knorr Lubricator Sales Co., Boston, Mass.; Madison-Kipp Corp., Madison, Wis.; McCord Radiator & Mfg. Co., Detroit, Mich.; Standard Oil Co. of Ind., Chicago, Ill.; The Texas Co., New York, N. Y.; and the Vacuum Oil Co., New York, N. Y.

Speed Reducers — Albaugh-Dover Mfg. Co., Chicago, Ill.; Boston Gear Works Sales Co., Norfolk Downs, Mass.; Cleveland Worm & Gear Co., Cleveland, Ohio; De Laval Steam Turbine Co., Trenton, N. J.; Falk Corp., Milwaukee, Wis.; Fawcus Machine Co., Pittsburgh, Pa.; Foote Bros. Gear & Machine Co., Chicago, Ill.; Wm. Ganschow Co., Chicago, Ill.; The Hill Clutch Machine & Foundry Co., Cleveland, Ohio; Horsburgh & Scott Co., Cleveland, Ohio; D. O. James Mfg. Co., Chicago, Ill.; W. A. Jones Foundry & Machine Co., Chicago, Ill.; R. D. Nuttall Co., Pittsburgh, Pa.; Philadelphia Gear Works, Philadelphia, Pa.; and Winfield H. Smith Co., Springville, N. Y.

Variable Speed Transmission—American Engineering Co., Philadelphia, Pa.; Columbia Vari-Speed Co., Chicago, Ill.; Lewellen Mfg. Co., Columbus, Ind.; Reeves Pulley Co., Columbus, Ind.; Moore & White Co., Philadelphia, Pa.; The Oilgear Co., Milwaukee, Wis.; and The Waterbury Tool Co., Waterbury, Conn.

Silent Gears—Chicago Rawhide Mfg. Co., Chicago, Ill.; Fibroc Insulation Co., Valparaiso, Ind.; The Formica Insulator Co., Cincinnati, Ohio; General Electric Co. (Fibroil and Textolite), Schenectady, N. Y.; and Westinghouse Electric & Mfg. Co. (Micarta), East Pittsburgh, Pa.

Miscellaneous — American Pulley Co., Philadelphia, Pa.; Conway Clutch Co., Cincinnati, Ohio; Edgemont Machine Co., Dayton, Ohio; B. F. Goodrich Rubber Co. (Cutless Bearings), Akron, Ohio; Midwest Steel & Supply Co.; The Rockwood Mfg. Co., Indianapolis, Ind.; and Twin Disc Clutch Co., Racine, Wis.

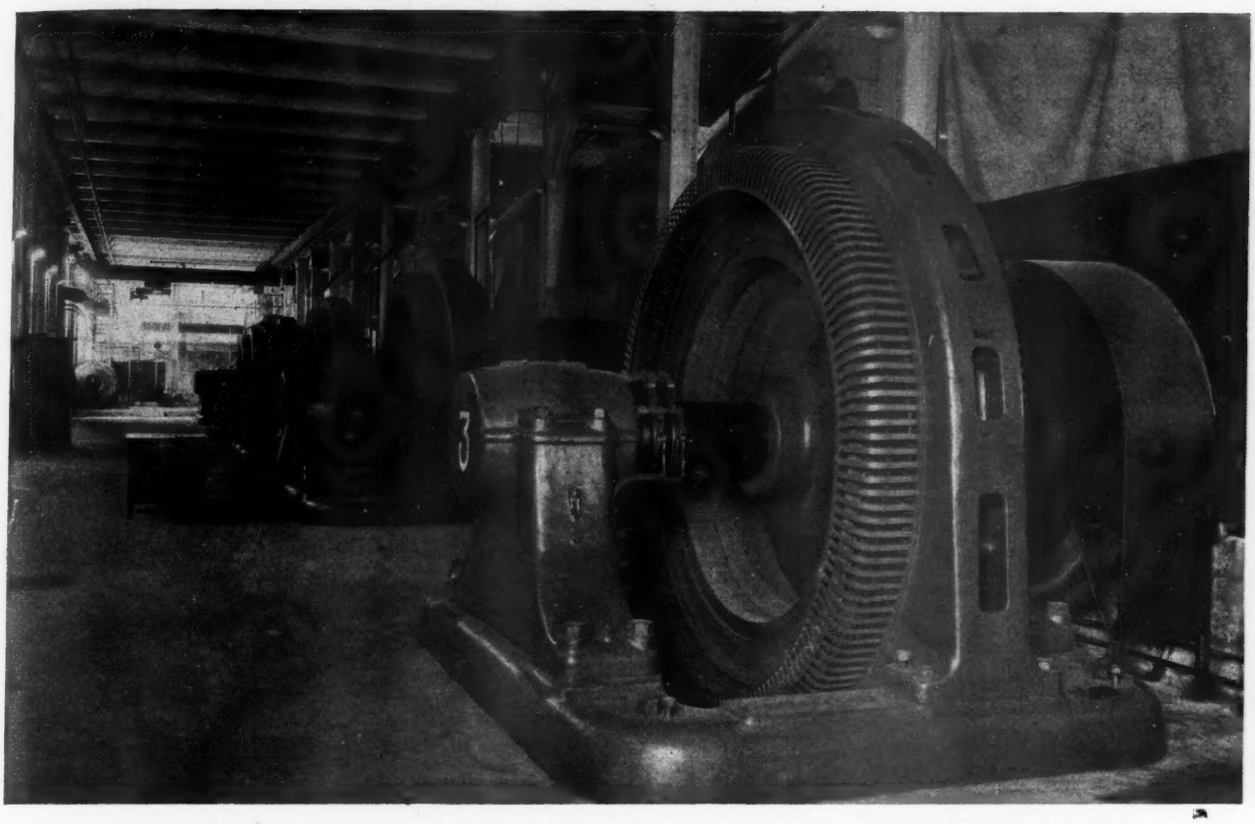


Fig. 1—The synchronous motor is beginning to come into its own.
Here are five of a row of seven General Electric, 2,400-hp., 2,200-volt, 240-r.p.m., synchronous motors driving magazine grinders in the paper mill of the St. Maurice Lumber Co.

Selection of Motors for Industrial Power Drives

including a discussion of the operating characteristics of the more common types, with special emphasis on the advantages of the synchronous motor

By PHILIP CHAPIN JONES
Electrical Engineer, The Goodyear Tire and Rubber Company, Inc., Akron, Ohio

DURING the past 30 years the advance of science and technology has been so rapid that new discoveries and inventions are buried under an avalanche of still newer ones long before they have been properly assimilated into the life of the country. Our great need is for a constant synthesis, an incessantly repeated effort to bring together related parts of our rapidly growing knowledge into a well-knit unit suitable for concrete application.

It is my purpose here to picture briefly an ideal industrial unit considered from the electrical power standpoint. I shall consider the various requirements of industrial drives and from available equipment so select that the resultant whole may incorporate what must always be our ideal in industry—a maximum of what is desirable at a minimum of cost.

In any ordinary large plant there is a distinct need for six types of motors. Obviously these six classifications are:

(1). Squirrel-cage induction motor.
(2) Wound-rotor induction motor.
(3) Direct-current shunt motor.
(4) Direct-current series motor.
(5) Direct-current compound wound motor.
(6) Synchronous motor.

Taken the country over, undoubtedly the vast majority of drives require merely an approximately constant-speed motor, easily stopped and started, but with no particularly abnormal starting or stopping torques. Arbitrarily, a normal starting torque could be defined as not over 50 per cent of the full-load torque. In this realm the squirrel-cage induction motor reigns supreme, and is thus naturally the most widely used form of motor.

I will not attempt to describe this well-known type of motor but will point out a few of its characteristics. The synchronous speed of this type of motor is fixed, depending upon the frequency and number of poles. The actual speed is less than the synchronous speed by the amount of the slip. The ordinary squirrel-cage motor has a slip of 3 to 5 per cent from no-load to full-load.

The squirrel-cage motor does not develop as high a starting torque as some other types. Slow-speed squirrel-cage motors will develop about 125 per cent of full-load torque, while high-speed motors will deliver up to 250 per cent of full-load torque at start, provided full voltage is applied to the primary. This will require a current at starting from six to seven times full-load current, which in most cases will be objectionable for motors larger than 5 hp. Hence, starting at reduced voltage is necessary, which in turn reduces the starting torque in proportion to the

square of the voltage. The operating characteristics of a typical polyphase squirrel-cage induction motor are shown in Fig. 4. This curve together with those shown in Figs. 2, 5, 7, 8, 11, 12 and 15 are taken from "Principles of Electric Motors and Control" by Gordon Fox.

The efficiency of squirrel-cage motors is poor at low speeds but is better in the higher speeds. Also, it is better in the larger capacities than in the smaller. A 5-hp., 1,200-r.p.m. motor has a full-load efficiency of approximately 86 per cent, whereas a 50-hp. motor of the same speed has an efficiency of nearly 90 per cent. The efficiencies range from 80 per cent in the 5-hp., 360-r.p.m. size to 92 per cent in the 50-hp., 1,800-r.p.m. size. Full-load efficiency curves for squirrel-cage motors are shown in Fig. 5.

The power factor of a squirrel-cage motor is very low at light loads and is also low in the low-speed types. The power factor gradually improves as the load on the motor approaches its rating, and will range from about 79 per cent for a 5-hp., 900-r.p.m. motor and 89 per cent for a 5-hp., 1,800-r.p.m. motor to 88 per cent for a 50-hp., 900-r.p.m. motor and to 93 per cent for a 50-hp., 1,800-r.p.m. motor. Power factor curves for squirrel-cage motors are shown in Fig. 6.

The squirrel-cage motor is excellently adapted for all classes of constant-speed drives which require moderate starting and running torques and where starting is infrequent. The great majority of fixed-speed drives fall in this class. Because of its lower first cost and simplicity, the squirrel-cage motor is generally preferred to the direct-current shunt motor for constant-speed duty. In many respects its characteristics are similar to those of the constant-speed shunt motor.

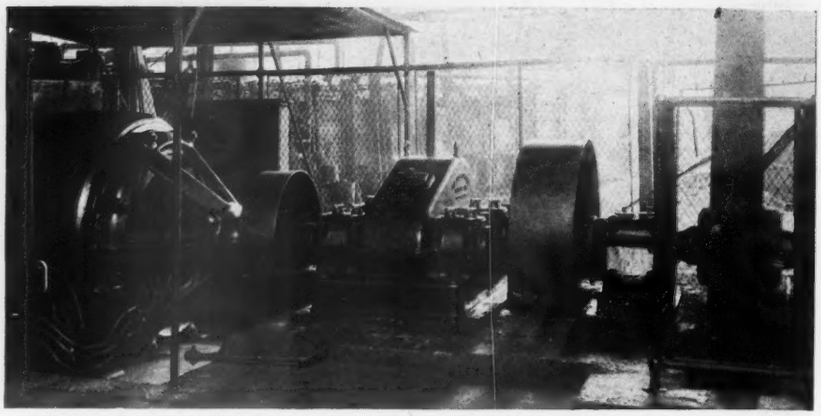


Fig. 3—The wound-rotor motor is unusually well adapted to drives that require flywheels.

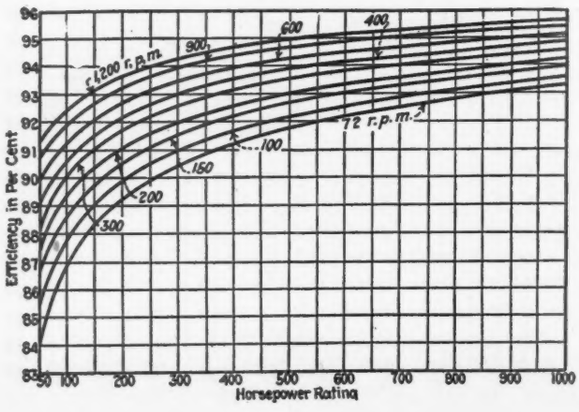
External resistance connected to the rotor winding makes the motor tend to slow up on the load peaks, thereby permitting the flywheel to carry the peak. After the peak passes, the induction motor speeds up the flywheel to its original speed. Hence, the flywheel carries the peak and there is no excessive peak power demand by the motor. This illustration shows a Westinghouse, wound-rotor motor connected through a speed reducer and flywheel to a steel mill drive.

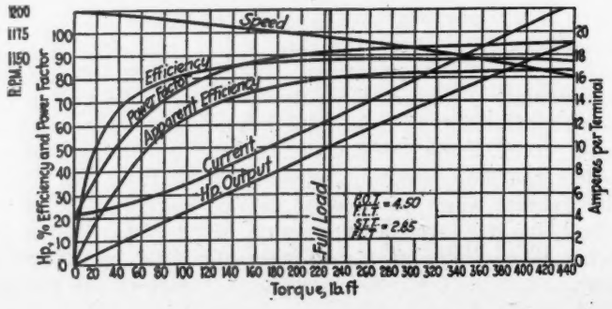
To get away from the disadvantage of using reduced starting voltage and consequent reduced starting torque, double-winding, squirrel-cage motors have been developed. These have a high-resistance winding that is effective during starting, and a low-resistance winding that comes into play after the motor comes up to speed. These motors do not require starters and are sometimes called high-torque motors because they will develop a starting torque of 2 to 2½ times full-load torque with three times full-load current. They are a more recent development, but are fast becoming popular.

The polyphase, wound-rotor induction motor is similar in general characteristics to a shunt-wound, direct-current motor having a speed regulating resistance in the armature circuit. At starting it develops full-load torque with full-load current. Speed may be varied by cutting resistance in or out of the rotor circuit; the speed will, however, also be dependent upon the load on the motor. The power factor of the wound-rotor motor is similar to that of the squirrel-cage motor, but varies with the torque that is developed rather than the horsepower output. Its efficiency is about the same as that of the direct-current, shunt motor. Characteristic curves for a typical wound-rotor motor are shown in Fig. 9.

The wound-rotor motor is used where frequent starting duty or where high starting torque, or moderate starting torque combined with low current input, are desired. Because the operating characteristics of the wound-rotor motor with external resistance are very much like those of the compound wound or series, direct-current motor (except as to efficiency), it is sometimes used for the service to which these types are adapted. The wound-rotor motor is particularly adapted to loads having a flywheel to carry them over high peaks. It is widely used for cranes and hoists, shears, presses, elevators, and similar manipulating duty.

The direct-current, shunt motor is a constant-speed motor, having only





Figs. 2 and 4—At the left are shown full-load efficiency curves of synchronous motors operating at 100 per cent power factor. At the right are shown characteristic curves of a typical, squirrel-cage, induction motor.

Comparative Operating Characteristics of Common Types of Industrial Motors†

Type of Motor	Starting Torque	Starting Current	Maximum Torque	Can Speed Be Adjusted	Effect of Load on Speed	Power Factor	Efficiency
General-purpose squirrel cage	D	A	C	No	C	High speed-B Low speed-C	B
Wound rotor	B	D	D	Yes-C	C	B—	C
Synchronous	D*	C	B	No	A	Adjustable	Slow speed, large size-A High speed, small size-C
Shunt	C	C	C	Yes-A	B		B
Series	A	E	A	Yes-B	D		B
Compound	B	D	B	Yes-B	C		B

The grading of A, B, C, etc., in each case indicates the relative degree that a given characteristic is possessed by each type of motor. Thus A indicates best, highest, or most; B indicates second best or second highest; C third best, etc. For instance, A in starting torque column indicates that the series motor has the highest starting torque, whereas A in the starting current column indicates that the general-purpose, squirrel-cage motor has the highest starting current.

†This tabulation represents in a general way what can be expected of average designs of motors of the types listed, which are in common usage, and is not intended to cover motors that have been especially designed for specific applications.

*This rating is obtained by the synchronous motors described by the author and is higher than that obtained from older designs of synchronous motors.

a small variation from no-load to full-load. The starting torque of this motor is about 150 per cent of full-load torque with 150 per cent current input. It is able to exert a good starting torque, but only at the expense of a large starting current. This motor will exert a breakdown torque of about 3½ times full-load torque. Its efficiency is very good and remains so over a considerable range of load. As a constant-speed motor it meets the requirements of a large range of industrial applications. Its characteristics render it the best suited direct-current motor for the majority of constant-speed drives that do not require excessive starting torque nor have high-speed loads. Characteristic curves for a shunt motor are shown in Fig. 13.

By varying the resistance in series with its shunt field, the shunt motor becomes an excellent adjustable-speed motor. It is extensively used for individual drives where a selective range of speeds is desired with good regulation at any point. High efficiency, easy and exact manipulation, together with steady running make this type of motor very satisfactory for adjustable-speed drives. Motors of this type are extensively used in machine tool work.

The series motor is essentially a high-torque motor. At standstill the torque may be several times full-load torque. Heavy overloads can be handled with good commutation. The series motor will start a much heavier load than will the shunt motor, and will accelerate with less current input. Its efficiency, however, is somewhat lower than that of the shunt motor. It is not a constant-speed motor, for the speed is low on heavy loads and high on light loads. In fact, this motor will run away if the load becomes too light. Characteristic curves for a series motor are shown in Fig. 7.

The series motor is extensively used on cranes and hoists, steel mill auxiliary drives, small ventilating fans, in electric traction service, and the like. The character of the load should be such that it increases rapidly with the speed.

The characteristics of the compound-wound motor combine in varying degrees those found in the series and shunt motors. Its speed decreases with increase of load and the torque increases rapidly with addition of load. It develops a high torque per unit of starting current and has a heavier breakdown torque than the shunt motor. It is a fairly constant speed motor with excellent pulling power on heavy loads, combined with good starting power. The characteristics of a typical compound motor are shown in Fig. 15.

The compound-wound motor is used extensively for driving pumps, compressors, shears, presses, reciprocating tools, and the like, where irregular loads with severe peaks are encountered, together with a demand for fairly constant speed.

The types of motors just discussed cover all of the mechanical requirements of most drives, but the complete and successful application of electric motors to industrial uses requires consideration of the entire power system from the turbines to the driven machine. The majority of all industrial drives use induction motors, which results in a moderate or low lagging power factor on the plant power system. This poor

Fig. 5—Full-load efficiencies of 60-cycle, polyphase, squirrel cage, induction motors.

Efficiencies for motors of different horsepower and speed ratings are given. These curves together with those shown for Figs. 2, 4, 7, 8, 11, 12, and 15 are from "Principles of Electric Motors and Control" by Gordon Fox, published by the McGraw-Hill Book Co.

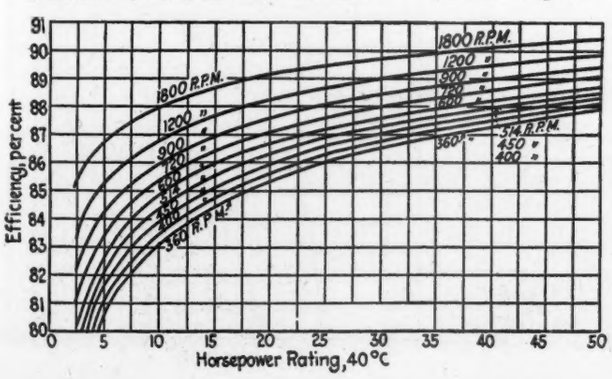
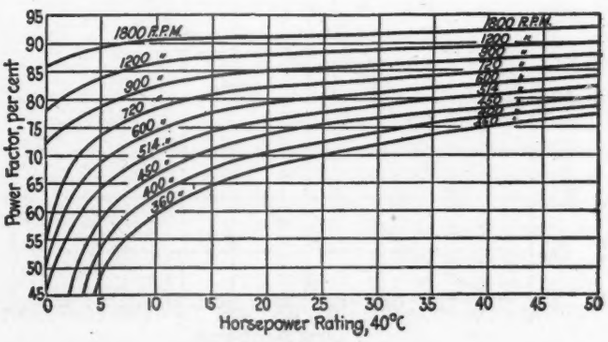


Fig. 6—Full-load power factor of 60-cycle, polyphase, squirrel cage, induction motors.



power factor in addition to causing poor regulation and increasing investment costs is the cause of a separate and distinct loss. This loss may be as high as 10 to 15 per cent of the cost of energy and is thus ordinarily well worth saving. A great deal may be done to hold up the power factor by keeping the induction motors loaded up to capacity, but the last step must invariably be made by other means.

Until comparatively recently the synchronous motor was considered very unsatisfactory, in fact almost impossible for general industrial use. This is because inherently it has no starting torque. It has been used from the very early days, but always where little or no torque was required in starting; that is, in conjunction with a clutch or some machine that could be unloaded, and often with an extra motor for starting it.

New developments are peculiar things. They seem to come when they will, forced on by undetermined causes. The recent development of high starting torque synchronous motors was not made possible by some new knowledge or discovery. All the factors in the design of such motors have been common knowledge for decades. The need has been as pressing. And yet for some reason it is only within the past few years that the super-synchronous motor, a synchronous motor that can be applied to any industrial drive, has made its appearance.

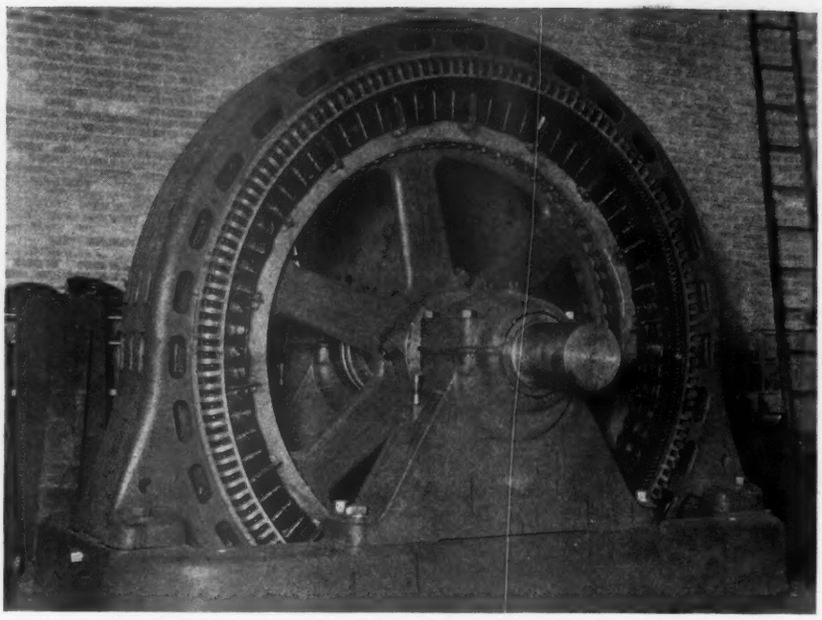


Fig. 8—High starting and pull-out torques characterize this synchronous motor.

It is rated at 600 hp., 80 per cent power factor, 100 r.p.m., 2,200 volts and develops a starting torque of 140 per cent of full-load torque, a 100 per cent pull-in torque, and a pull-out torque of 350 per cent of full-load torque. This Electric Machinery Co. motor is located in the plant of the Goodyear Tire and Rubber Co., Akron, Ohio.

We have always wanted such motors because of their electrical characteristics, and their use has now been made possible because of the torque characteristics recently worked into their design. The economic utilization of the synchronous motor, however, is ordinarily justified only in the larger sizes and lower speeds. In the smaller sizes the cost per horsepower is high compared to induction motors. We can buy induction motors for $5 to $8 per horsepower, while for equivalent synchronous motors one must pay from $10 to $20 per horsepower. This is particularly true at the normal speeds, say 600 r.p.m. and above. On the other hand, at very low speeds the cost of induction motors per horsepower rapidly rises

Fig. 7—Operating characteristics of a typical, series motor.

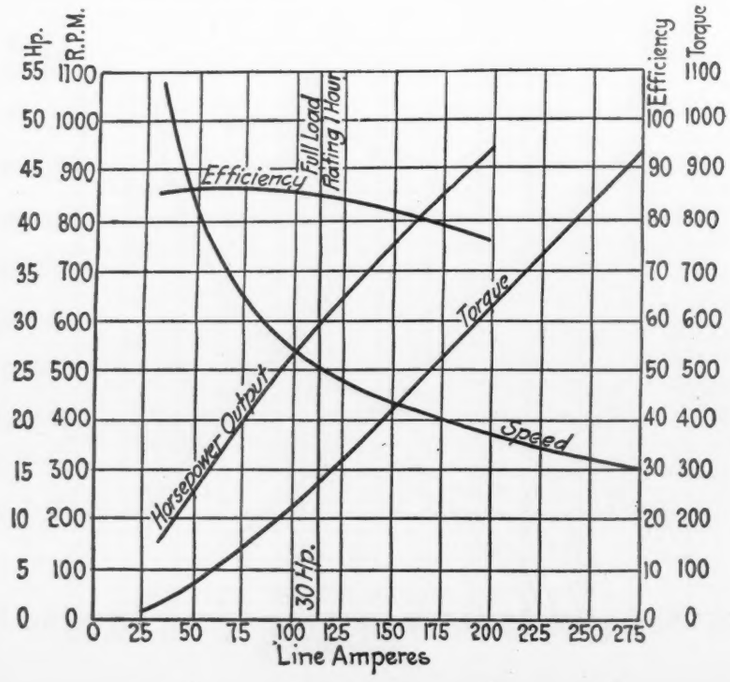
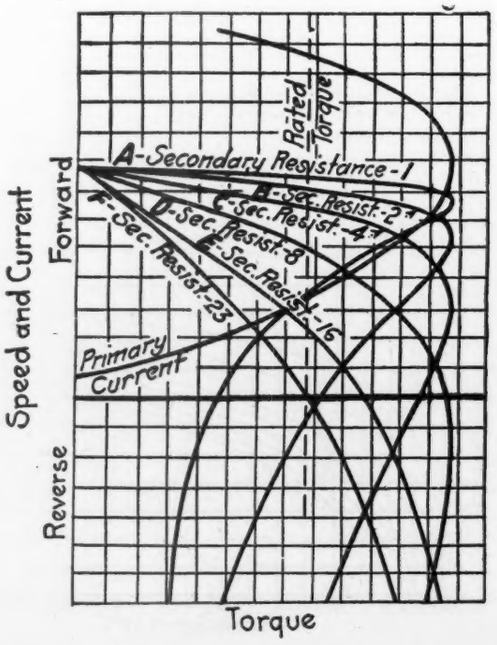


Fig. 9—Speed, torque, and current curves of a polyphase, wound-rotor motor with different values of secondary resistance.



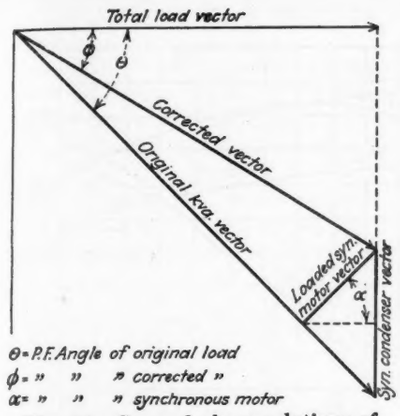

Total load vector
Corrected vector
Original kva. vector
Loaded syn. motor vector
Syn. condenser vector
θ = P.F. Angle of original load
ϕ = " " " corrected "
α = " " " synchronous motor

Fig. 10—General phase relations of load using induction motors operating at 70 per cent power factor.

and their power factor abruptly declines. For this reason a low-speed synchronous motor may sometimes be used in place of a higher-speed induction motor and a reducing gear unit. It is not unusual to find that the combined cost of a high-speed induction motor and a reducing gear unit is as much as, or more than, that of a low-speed synchronous motor. When the difference in overall efficiency of the two possibilities is capitalized the chances are even greater for such to be the case. Here, then, is the big field for the synchronous motor, and assuming that it is under such circumstances that these motors are to be used, I shall point out some of the more important factors that make them so desirable from an electrical standpoint and so easy to use from a torque standpoint.

In the past it has been almost universal practice to use synchronous condensers for power factor correction. In recent years the use of static condensers has been urged. There are undoubtedly many places where both of these corrective means can be used to advantage, but in the average industrial plant there are two potent factors which drag down the balance arm in favor of the loaded synchronous motor.

Fig. 10 shows the general phase relations of the load of an ordinary induction motor plant operating at 70 per cent power factor. It is obvious that more corrective kva. is required if a condenser is used when the correcting vector rises vertically from the lower end of the initial load vector than when some of the existing load is driven by a synchronous motor and the resulting vector starts from farther up on the load vector. Just how much difference this makes is shown by Fig. 12 in which is plotted, for the same amounts of correction, the ratio of kva. of condenser capacity to kva. of loaded synchronous motor capacity when the latter is operated at its most effective power factor. The abscissas are original power factor. It will be noted that at the original power factor shown in Fig. 10, 43 per cent more capacity would be required were condensers used. Had the original power factor been 50 per cent the saving in capacity by the use of loaded synchronous motors would have been 100 per cent of the synchronous motor capacity.

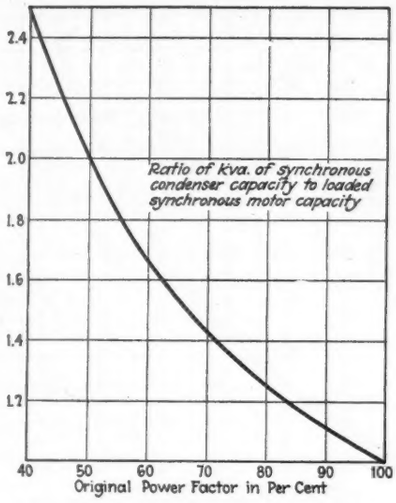
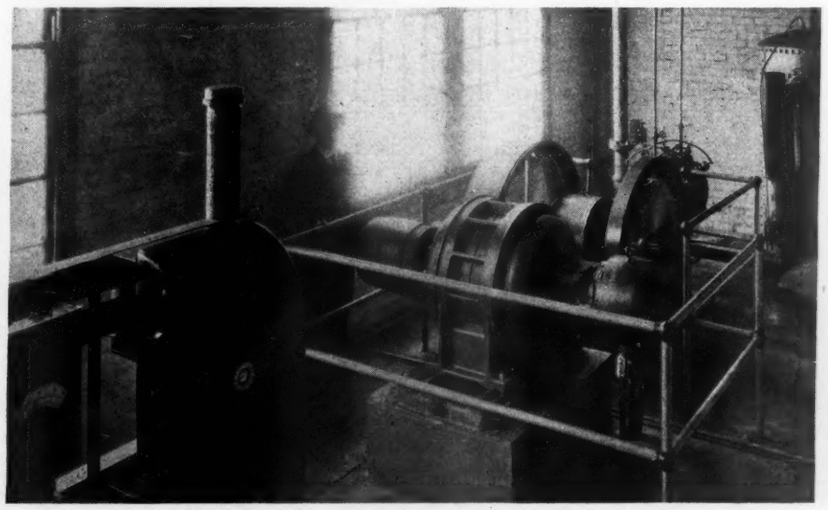


Fig. 12—This shows the ratio of synchronous condenser capacity to loaded synchronous motor capacity when the latter is operated at its most effective power factor.

Fig. 11—Here is a general-purpose synchronous motor used on an air compressor drive.

This General Electric motor is rated at 75 hp., 80 per cent power factor, 900 r.p.m., 220 volts and is installed at the Butler (Pa.) plant of the Fretz-Moon Tube Co. In addition to carrying the air compressor load it raises the plant power factor from 75 to 98 per cent. This motor is controlled through the medium of the manually-operated compensator shown at the left, a field switch, discharge resistance, field rheostat, field current ammeter and line ammeter.



This saving in capacity obviously means a saving in investment in corrective equipment. In any power factor correction problem, the subject of cost of correction is always of vital interest. Inherently a large part of this cost is fixed charges on corrective equipment. When synchronous motors are used in place of synchronous or static condensers, a saving is made in corrective capacity which is synonymous with investment cost, and thus the cost of correction is attacked on its main front. A still further reduction in investment charges is possible, because with loaded synchronous motors only that part of the motor cost which is above the amount which must be paid for some cheaper type of drive, say an induction motor, is chargeable to the correction account. It is thus evident that the use of loaded synchronous motors for corrective purposes, cutting down the investment cost in the two ways noted above, gives correction for a much lower figure than would otherwise be obtained. Often the correction is obtained at no cost at all.

As I have indicated before, the great fact that has retarded the use of synchronous motors is lack of torque at other than synchronous speed. Inherently it has zero starting torque and a low pull-in torque. The big development which has recently made the synchronous motor possible industrially is its change into a hybrid machine, half induction motor and half synchronous motor.

The induction part of the motor is used for starting, and the synchro-

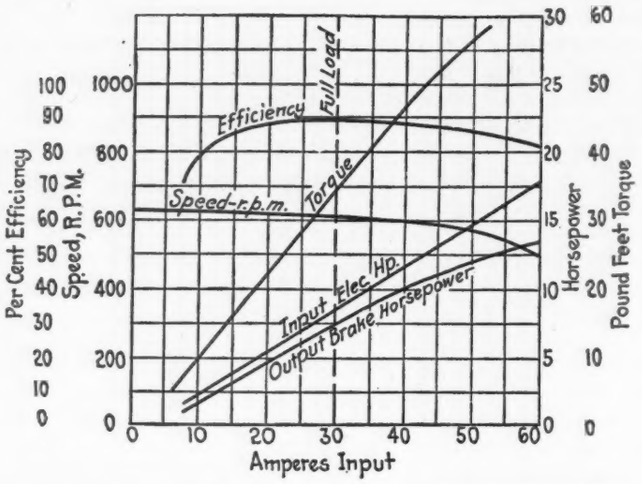


Fig. 13—Characteristic curves of a typical shunt motor.

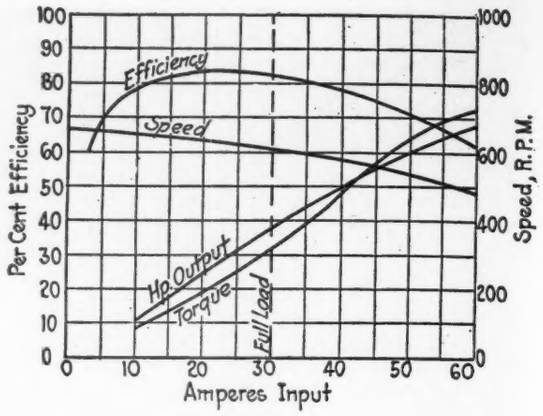


Fig. 15—Operating characteristics of a compound motor having 20 per cent series field.

nous part for running. By one method or another, a large number of relatively high-resistance bars are threaded through the faces of the poles and a very effective squirrel-cage rotor is thus formed. The resulting combined torque characteristics given to the motor are very satisfactory. Anything in reason may be obtained. The company with which the writer is associated has installed synchronous motors having starting torques of 140 per cent, pull-in torques of 100 per cent, and pull-out torques of 350 per cent of full-load torque. Such a motor is shown in Fig. 8.

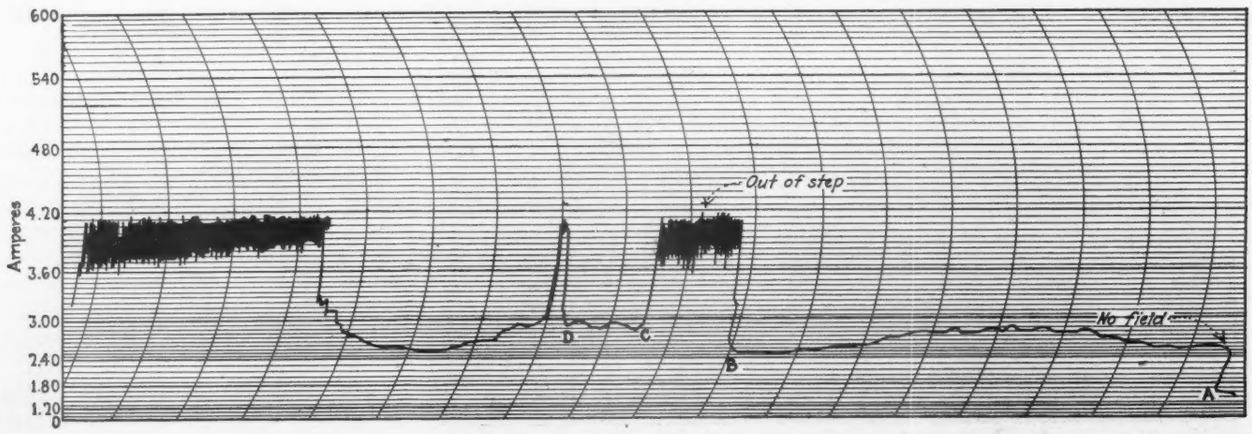
There has been, however, one other disadvantage of the synchronous motor compared to the induction motor, which I have not yet mentioned. It has always carried around with it a lot of excess baggage in the form of excitation equipment such as belt-driven exciters, exciter field rheostats, motor field rheostats, ammeters, and similar equipment. In the adaptation of the synchronous motor to industrial uses one of the important steps has been the elimination of this equipment. Most large plants have a direct-current distribution system. Where this is the case, advantage may be taken of it and the exciter and all rheostats and meters may be entirely discarded. The fields may be designed to operate on the system voltage with a liberal heat rating. Any voltage changes then only slightly modify the power factor. In our own plant we use no field equipment excepting one field contactor operated by a relay which in turn is actuated either by the secondary frequency, the primary current, or time. At the proper moment the field is automatically thrown on or dropped off and no adjustment or attention is needed.

This shift has, however, decreased the reliability of the excitation. Where the field current is taken from the plant system we must face the possibility of failure of the field without failure of the a.c. side. However, by the improvements of rotor design mentioned before, making high, squirrel-cage torques available immediately on failure of the field we have a motor which will carry its load even without a field.

The remaining step which has already been taken is to build heat capacity into the motor so that when the field fails and the motor starts to operate as an induction motor and thus take a larger stator current as well as a rotor current, there will be no overheating for a reasonable time —such a time as is ordinarily required to restore the d.c. service. As a measure of the heat capacity we have been specifying that the motor shall operate for 15 min. as an induction motor at full load without dangerous overheating. This would mean that the maximum temperatures should not exceed those given by the A.I.E.E. Standardization

Fig. 14—Operating a synchronous motor without a direct-current field.

At *A*, while the motor was under normal load, the field switch was pulled and the line current drawn by the motor increased from 150 amp. to approximately 260 amp. The significant fact is that the motor did not pull out of step. At *B* a peak load came on, incident to starting a new load cycle, and the motor pulled out of step and operated that way until the load dropped enough to allow it to pull back into step, as at *C*. This graphic chart was taken on a 600-hp., 2,200-volt, 100-r.p.m., synchronous motor having a full-load current at unity power factor of approximately 125 amp.



Rules for the various classes of insulation.

The ability of a well-designed synchronous motor to carry its load for short periods without excitation is well illustrated by the chart shown in Fig. 14. Here a graphic ammeter was connected in the circuit feeding a 2,200-volt, 600-hp., 100-r.p.m., synchronous motor. The load follows a 6-min. cycle. The current during most of the cycle is between 130 and 150 amp. In Fig. 14 at *A* at the right-hand end of the chart, the current is just about this value.

At this point the field was opened and immediately the current approximately doubled. The significant fact is that the motor did not pull out of step. About the middle of the chart, however, a new cycle is begun and the peak load at the beginning at point *B* pulls the motor out of step. This is evidenced by the large increase in current and the oscillation of the instrument pen at slip frequency, between *B* and *C* in Fig. 13. Shortly the load drops somewhat, and the motor pulls back into step at *C*, only to be pulled out again for a brief interval a few moments later. The points where it pulls out of step and drops in again are distinctly evident. This shows very clearly how short interruptions to the excitation may be inconsequential so far as the operation of the motor goes.

There is one other possibility offered by the synchronous motor of which advantage has been taken. It can be stopped very quickly by dynamic braking; that is, by disconnecting the armature from the line and connecting it to a resistance, leaving the field connected to the direct-current power supply. The motor then acts as a generator and the retarding torque may be adjusted by changing the resistance into which it is discharging. On drives where it is necessary to have an emergency means of stopping, this becomes very desirable, for in itself the synchronous motor comprises not only a very satisfactory slow-speed motor, but also an equally satisfactory brake. When the field is supplied from the plant direct-current distribution system and the motor is to be used for dynamic braking, means must be taken to stop the motor automatically on failure of the direct-current, power supply.

This completes the picture I have roughly attempted to sketch. It comprehends the entire industrial world in which the vast majority of the motors, and by far the largest part of the load, consists of induction motors with their relatively low average power factor. To make this load economical from an electrical standpoint, something is required to raise the power factor. For this purpose therefore, it is suggested that a small number of large synchronous motors be scattered systematically around the plant. Each will carry load so as to operate at a power factor which will make its corrective effect most useful. The resultant whole will then be satisfactory both from the mechanical and the electrical standpoints.

Control of Window Light Deserves Attention

ALTHOUGH reflectors are employed almost universally today in the artificial lighting of factories, offices and other buildings, to direct the light where it is needed and to insure that the largest possible volume of light will be available, we have not given much attention to the control of natural light that pours in through the windows. The inconsistency of this was presented with most interesting evidence and many practical suggestions by Professor H. H. Higbie of the University of Michigan, speaking before the Twentieth Anniversary Convention of the Illuminating Engineering Society.

Discussing the effect of the various means of control upon the quantity and quality of the window illumination, Professor Higbie presented data from numerous surveys embracing shades covering top of window, shades covering bottom of window and Venetian blinds covering the whole of the window. "So far, all our findings appear to indicate," he said, "that control of light from windows by means of Venetian blinds is better than control by shades covering the lower sash, which itself is better than control by shades covering the upper sash."

"Whatever may be the merits of using roller shades of material having good transmitting properties, the fact remains that most window shades in ordinary use transmit very little, and such control as they exercise is by merely absorbing and destroying the light. In contrast with such a wasteful method, the Venetian blind presents a solution of the problem which seems to have great possibilities, in that the light may be redirected and made useful instead of being absorbed. If the slats be sloped up inward, the light from sun and sky is largely reflected back out of doors and all values of illumination in the room, maximum and average as well as minimum, should be decreased. If the slats be sloped down inward (or up outward) and are of light color so as to have good reflecting value, a considerable part of the light striking the window from outside, which otherwise would pile up near the window where not needed, is either thrown directly to the rear of the room where most needed or is thrown first to the ceiling and from it reflected more or less effectively back to working planes preponderantly at the rear of the room.

"The result obtained by changing the slope of the slats is easy to follow with the unaided eye, it being possible to throw a vaguely defined bright zone across the ceiling to the rear wall; and by means of a photometer it is easily shown that great increases may be produced in either the horizontal or vertical illumination at the rear of the room, with corresponding decreases in the maximum illumination near the windows."

In an analysis of natural illumination through Venetian blinds, Professor Higbie said: "From a theoretical viewpoint it appears that Venetian blinds, properly constructed and used, should have an advantage over all the ordinary types of window shades in that they are able to redistribute the light which they intercept and render it useful, instead of merely absorbing and destroying it. Control of natural illumination in interiors by means of roller shades which cover the upper part of the window is the least desirable method. It is better to use shades which cover the lower portion of the window, the roller being mounted at the meeting rail of the upper and lower sash, or at the window sill, or adjustable in height. It is best to use Venetian blinds, which operate to redistribute the light rather than to absorb it. In some cases such blinds may be adjusted so as to render the illumination not only better distributed but actually higher at critical points than it would be with bare windows. The amount of improvement of illumination depends upon a proper finish of the slats for high reflecting power, and upon a proper adjustment of their angle. In the cases tested, this angle lay between horizontal and thirty degrees below horizontal as we look along the slats into the room."

Getting the Most from Silent Chain Drives

used in industrial plants, by making sure that they are properly designed for the service conditions, carefully installed, and given the necessary attention

By A. B. WRAY
Chief Engineer, Morse Chain Co., Ithaca, N. Y.

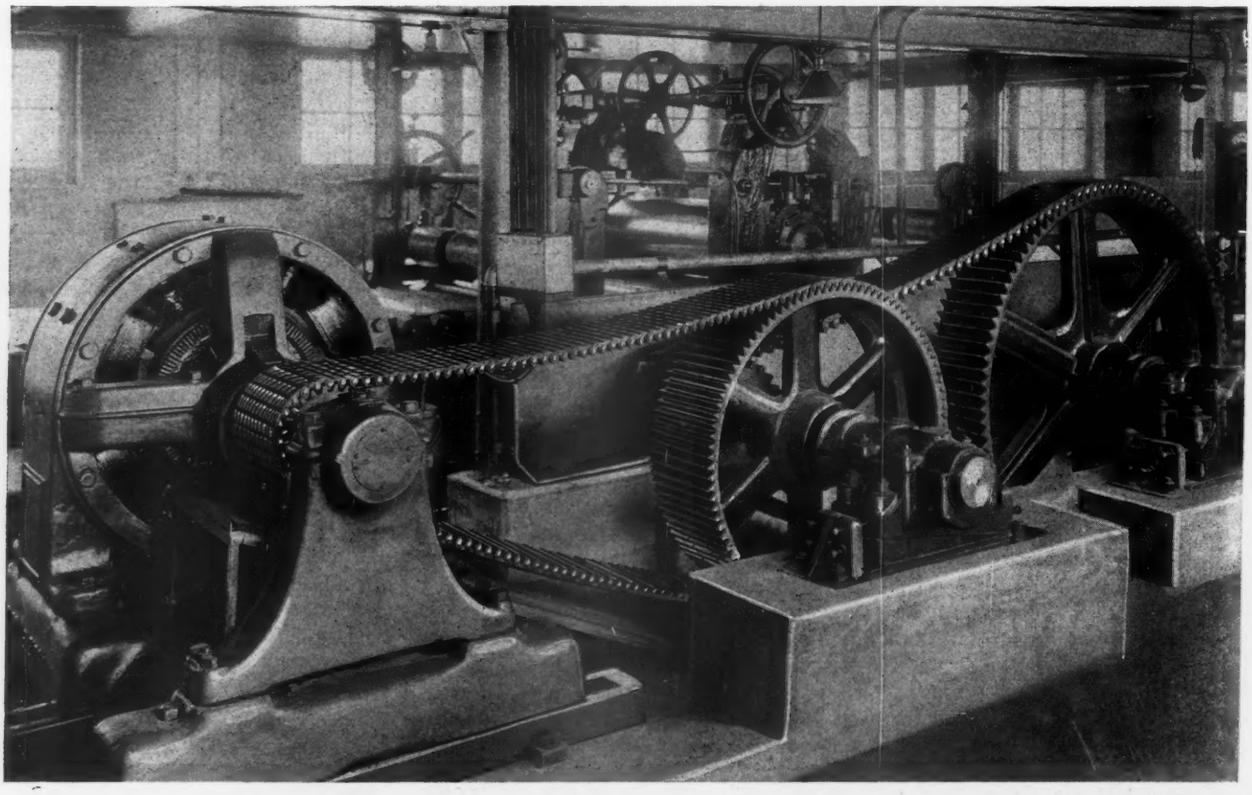
THE silent chain drive is becoming a factor of ever increasing importance in the transmission of power. Inasmuch as they are made in sizes ranging all the way from the drive employed in the head of a sewing machine to those that transmit 1,000 or more horsepower in rolling mills and similar installations, their field of application is very large. The development of the electric motor gave great impetus to the use of silent chain drives, as electric motors can be built in almost any size desired and installed close to the driven shaft, the only factor limiting this distance being the form of transmission used. It was not always feasible or satisfactory to use a belt drive. On the other hand, a gear drive is noisy and often precluded placing the motor at the most advantageous place. Under these conditions, the silent chain drive has offered a number of worth-while advantages which have been appreciated by industrial plant operators.

The policy of the silent chain drive manufacturers has had a good deal to do with the success of this type of drive. They have preferred to design the drives themselves after having full specifications covering the requirements. They have considered each application as an engineering proposition and recommended what they considered most suitable for the conditions, thus avoiding troubles that would occur if the design had been selected by one who is not a specialist or familiar with designing this type of drive. There have, of course, been failures, but the manufacturers have either furnished replacements to make the drive successful, or took it back on a basis that kept the confidence of the users.

There are engineers who believe that their service requirements are unusual; that the product going through the machines is too delicate for a positive drive. For a number of years textile mills, particularly, were fearful that the positive drive could not be used on certain of their machines. Fifteen years of successful service on spinning frames, twister frames, spoolers and preparation machines has demonstrated that few, if any, of these machines cannot be driven to advantage by silent chain drives.

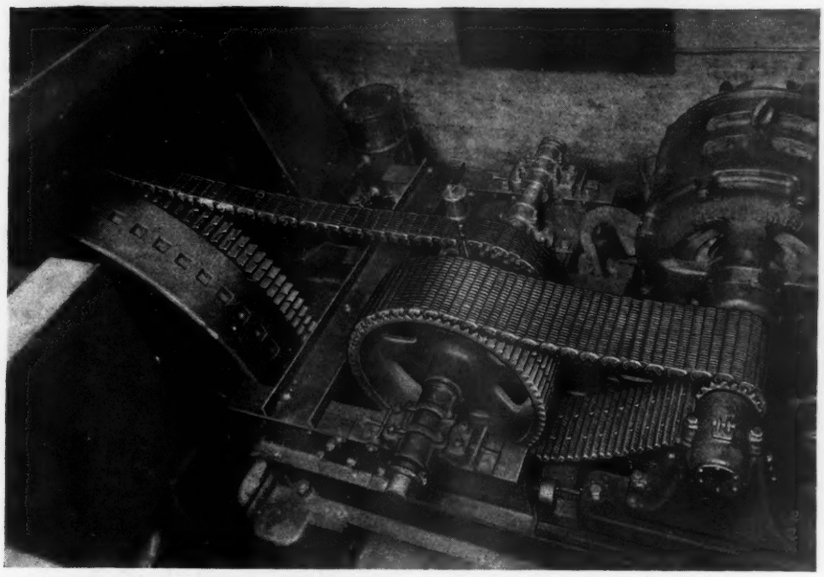
Some operators have been afraid of their machines jamming, thus breaking the machine and spoiling the work, but seldom have their fears been justified. The chain drive manufacturers are in position to furnish shearing pins or slip sprockets where something of this kind is really necessary.

There are today very few machine tools that are not furnished with



This shows a double-reduction chain drive to a set of rolls in a lead mill.

The first reduction is from 250 to 63 r.p.m.; the second reduction is from 63 to 19.7 r.p.m. Both chains operate on 120-in. centers. The motor is rated at 125 hp.



Here an ammonia compressor is driven through a double-reduction chain drive.

The first reduction is from 850 to 198 r.p.m. The chain is 10 in. wide and operates on a center distance of 36 in. For the second reduction of 198 to 45 r.p.m. a 5-in. chain is used, which operates on 84-in. centers. The motor is rated at 75 hp.

individual motor connected through a silent chain drive, and while driving the motor is the principal use on machine tools, a chain is often used to replace a train of gears, or other drives for the feed auxiliaries and special mechanisms. Engineers with special problems to solve have come to the silent chain manufacturers and so there have been developed special uses and special chains for a large variety of purposes.

Thus, the manufacturers of hoisting machinery, power shovels, ditching machinery, dredges, and the like have found the silent chain drive ideal as a connection between the electric motors or gas engines that drive the machine. Gearing would be noisy and preclude placing the motor or engine at the most advantageous point. Belting is out of the question for such applications.

Silent chain drives have been used for a good many years in steel and brass rolling mills on hot rolls, cold rolls, wire drawing benches, and so on. The quality of the work produced has been superior to that produced on similar machines with other types of drives.

In large power drives such as are used in rolling mills and power stations, the chains often transmit over 1,000 hp. In such installations, a silent chain has the advantage that it gives a positive drive and requires only a short center distance between the two shafts. The largest chain drive ever constructed transmits 5,000 hp.

Manufacturers of refractory bricks have for a good many years found that the silent chain drive meets their requirements better than any other form of drive. The service is unusually severe and the drive does not give the life that it does under more favorable conditions, but on direct comparison of results obtained with other types of drive they find the chain drive to be the most economical.

Printing establishments are large users of silent chain drives. Most of the large city newspapers use silent chains for driving the multiple presses. At first the chain manufacturers felt that the drive was ideal for the rotary presses, but were a little afraid of the flatbed and color presses on account of the reciprocating motion of the bed. In the past few years a great many of these presses have been successfully driven. When proper attention has been given to the dashpots on the presses, chain drive has not caused any trouble.

The manufacturers of silent chain drives do not claim that their drive should be used on every possible application. Their success has largely come from considering each drive as an engineering proposition and recommending a chain drive only where they felt that it was better than any other form of drive. Drives on extremely long centers are not suited for silent chain; nor are drives on excessively short centers. Very often a silent chain drive can be used on the same centers as a gear drive, but this is accomplished by the use of smaller sprockets. Machines that operate with a reciprocating motion, or that impose vibratory or shock loads, should be looked to with care. Of course, if there is a sufficiently large balance wheel the load becomes fairly uniform, or a spring sprocket can be used to re-

In this case a 6-in. moulder is driven by a 10-hp. motor through a silent chain.

The reduction is from 1,500 to 800 r.p.m. Distance between centers is 18 in.

lieve the chain from the shock. This will improve the operation, but does not correct the trouble as does the balance wheel.

There have been cases of misapplication and abuse of the chain drive and the chain manufacturers have tried hard to educate their users so as to avoid these dangers and troubles.

It must be borne in mind, however, that the proper selection, installation and maintenance of a silent chain have much to do with the reliability and quality of service that a chain drive will give. This is equally true of every piece of equipment.

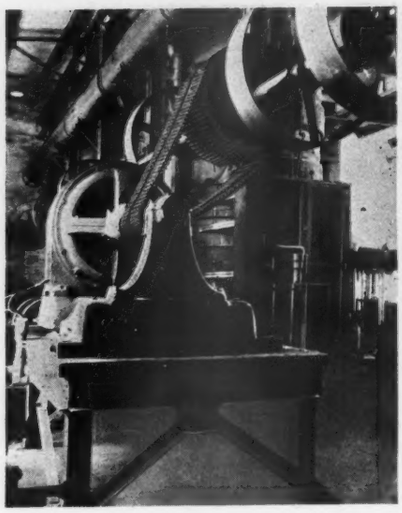
The principal factors influencing the design of a silent chain drive are the power to be transmitted, the speeds of the driving and driven shafts, the center distance, and the service. The higher the rotative speed, the smaller the pitch it is necessary to use. All manufacturers of silent chain drives use circular pitch. For mechanical reasons, it is not good practice to make a chain more than approximately 12 times the pitch in width. This limits the amount of power that can be transmitted by a certain pitch, although it is possible to use multiple-strand drives, as many as four strands having been used successfully on a single drive.

It may be interesting to discuss for a moment some of the points that must be considered in laying out a chain drive.

Briefly, designing a silent chain drive consists in selecting the proper pitch, width of chain and number of teeth in the sprockets, and determining the shortest center distance for best operation, unless the center distance is fixed by other conditions.

The first step is to determine the proper pitch. In almost every case it is desirable to use the largest pitch possible and yet not exceed the maximum allowable rotative speed for that pitch. In some cases it is permissible to use a certain pitch at higher rotative speeds than would ordinarily be allowable for that pitch. When only small amounts of power are to be transmitted, it is sometimes necessary to use a smaller pitch than the rotative speeds would indicate, on account of the extremely narrow chain that would be called for in the larger pitch.

The second step is to select the proper number of teeth for the driver and driven sprockets. We have compiled a data table that shows the minimum number of teeth for the driver sprocket and the maximum desirable for the driven one, with the desirable number of teeth for both. With this information we proceed to determine the number of teeth in the sprockets, working this out in the form of a proportion as follows:



Lineshafts are frequently driven through silent chains.

This chain transmits 200 hp. and gives a reduction of 575 to 154. It operates on 48-in. centers.

Silent chain drives may be used to transmit small as well as large amounts of power.

The sewing machines are operated from a lineshaft which is driven by a 2-hp. motor through a silent chain 1¼ in. wide. The distance between centers is 18 in. and the chain gives a reduction of 1,100 to 417 r.p.m.

Driver r.p.m. ÷ driven r.p.m. = driven teeth ÷ driver teeth

Having selected the number of teeth in the sprockets, we proceed to figure the chain speed in feet per minute, using the following formula:

(Driver teeth × r.p.m. × pitch) ÷ 12 = feet per minute

Having found the chain speed and knowing the horsepower to be transmitted, the total pull of the tight or driving strand of the chain is determined by using the following formula:

(Hp. × 33,000) ÷ feet per minute = total pull

Knowing the total pull, the next step is to select the width of chain. The table shows the allowable pull per inch in width for the different pitches. This, divided into the total pull, gives the width of the chain. It is always advisable to use the next wider chain than called for by the following formula:

Total pull ÷ allowable pull per inch = width in inches

In a good many cases where service is continuous or severe, an extra-wide chain should be selected.

In motor drives the driver sprocket is almost always made of steel and hardened. It is only where there are a relatively large number of teeth in the driver sprocket and where the rotative speed is slow that it is safe to use sprockets made from semi-nickel steel castings or cast iron. Large cast-iron sprockets may be made up solid, split, spring or shearing pin type, according to the requirements and service.

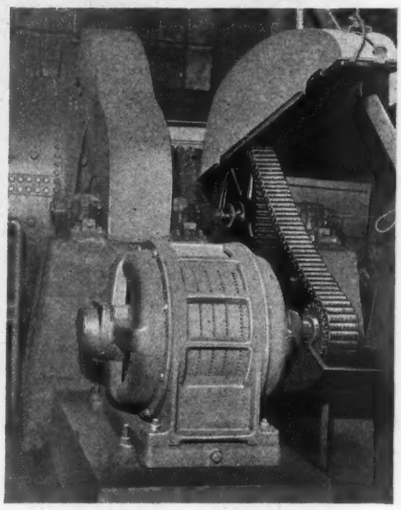
The designer of a silent chain drive has some choice as to pitch. If he wants a very quiet running drive, he will use a smaller pitch than designated. On a variable-speed drive he will sometimes select a pitch that will be over-speeded at the high speed, knowing that the drive will not run much of the time at that speed. If other conditions are favorable, he will sometimes select a shorter center distance than would ordinarily be suggested.

As mentioned previously, there are certain machines that are not suited for silent chain drives. These are machines that operate with a reciprocating motion, with only a very small or no balance wheel. Sometimes machines of that type can be driven by means of a spring sprocket. A spring sprocket has a rim mounted on the hub that is kept in balance by compression springs. These springs relieve the strain on the chain as the load changes.

Some machines are likely to stall and the users feel that a belt will slip and throw off in case of stalling, but the silent chain manufacturer is in position to furnish a shearing pin sprocket in which the number of pins can be varied so as to shear at any desired load. These pins can easily be renewed, in case they shear.

To get the best results from a silent chain drive, the installation should be made rigid. This calls for a good foundation; foundations and bearings should be rigid to prevent vibration or springing of the shafts. The sprockets must be carefully aligned and should be mounted near enough to a bearing to prevent any tendency of the shafts to spring, and should be securely fastened on the shaft to prevent shifting or misalignment. The shafts must be level and parallel with each other. When split sprockets are used, great care should be taken not to bruise the fracture where the halves go together. The bolts should be tightened equally, so as to bring no undue strain on the sprocket, which might cause failure.

Care should be used not to drive keys in too hard. When installing spring sprockets or shearing pin sprockets, be sure to see that these are properly lubricated between the rim and inner member. When installing the shearing pin sprockets, it is suggested that only two shearing bolts be used at first. If these shear too easily, additional bolts can be added. Remember, too, that a

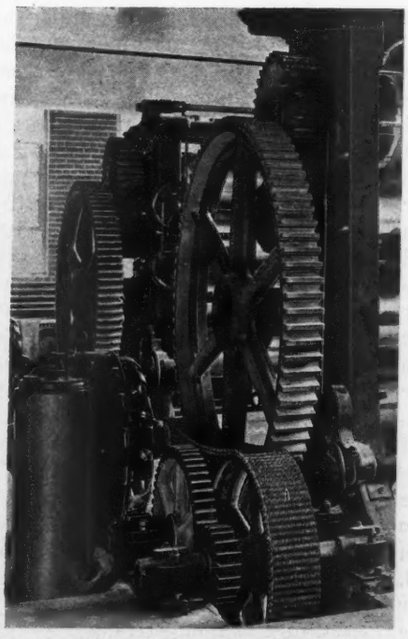


This silent chain is rated at 60 hp. and drives a ball mill.

silent chain should never be run tight. This prevents the proper action of the joint and proper engagement of the chain with the sprocket teeth. In consequence, it causes unnecessary pressure on the bearings and reduces the efficiency of the drive.

Be sure that the joint pins are properly inserted in the chain, as shown in the literature of the chain manufacturer, and the washers securely riveted.

After the installation of a chain drive is complete, it should be carefully examined to make sure that it is operating properly, before it is put into service. Failure to do this may cause trouble.



This is one of three 50-hp. silent chain drives on the calenders in a rubber factory.

Operating on 54-in. centers, this chain gives a reduction of 690 to 138 r.p.m. It is 6 in. wide.

No piece of equipment will continue to operate at its highest efficiency without a certain amount of attention, and chain drives are no exception to this rule. Therefore, be sure that the drive is kept rigid, the sprockets in line and the shafts parallel. Misalignment of the shafts often occurs, due to shrinkage of timbers or settling of the building. The chain should be kept well lubricated, using oil when possible to do so. Greasing is often sufficient on large drives. If the chain becomes gummed up, it should be cleaned with kerosene and then thoroughly oiled before it is put back in service.

Sometimes there is a tendency for links in the chain to crowd together, or for the pins to protrude. This is the result of insufficient lubrication on starting and the cutting of the links as the chain flexes. This condition can usually be corrected and overcome by taking a screwdriver or chisel and spreading the links apart, and then thoroughly lubricating with a heavy oil. The oil used should be heavy enough to prevent the crowding together of the links.

A drive should usually be encased for safety and to prevent dust and grit getting into the chain. It is not necessary to run the chain in an oil bath, although this is often done, as under most conditions it can get along with considerably less lubrication.

On drives where the load is pulsating, slack should be kept to a minimum. On the other hand, no chain drive should ever be run with initial tension. In a vertical drive the slack in the chain should be watched to see that it does not become excessive; otherwise serious trouble may develop.

Although a good silent chain has years of service built into it, and will deliver this service if it is given the proper chance to do so, it will not run forever. However, it gives plenty of warning that wear is taking its toll, the lengthening in pitch being visible by noting how far out on the teeth of the sprocket the chain climbs. The silent chain adjusts itself to its true pitch circle on the sprockets and eventually reaches a point where it will jump over and skip the teeth. It should be replaced before this point is reached, as otherwise it will destroy the sprockets.

Methods of

Reducing Friction Losses

in power drive equipment by using better bearings and rearranging drives to improve operation

By G. A. VAN BRUNT
Managing Editor, Industrial Engineer

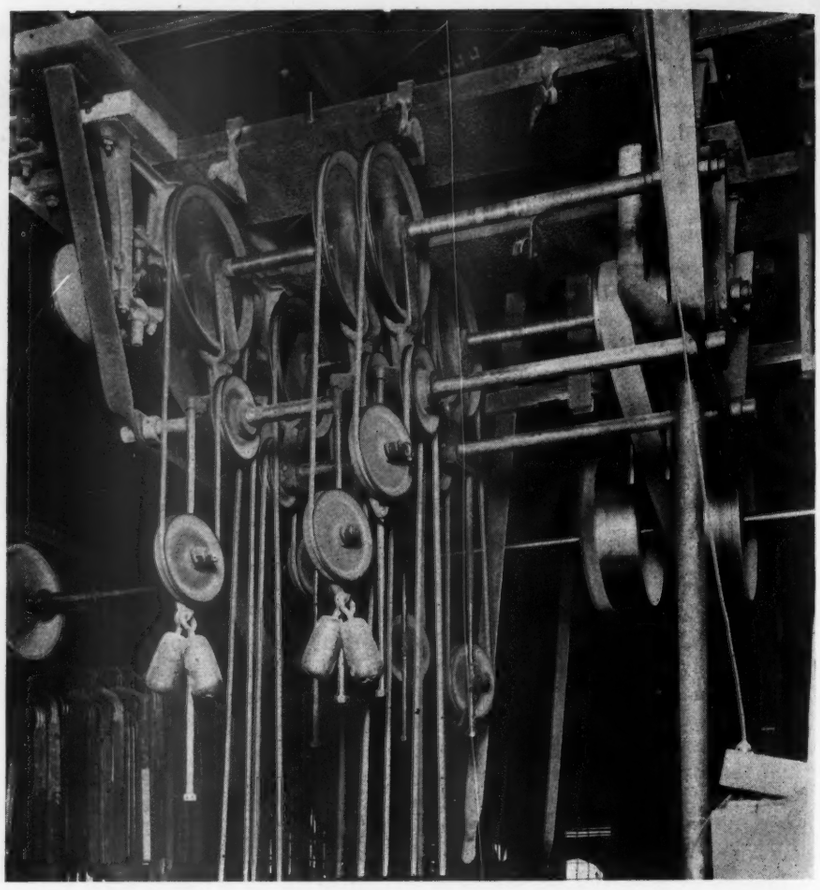
IN THE process of transmitting mechanical energy from the motor through belts, gears, or chains to the spindle of the driven machine there is a loss of power. This loss may be comparatively large or small, depending on the type of mechanical power drive equipment used, its condition, and several other factors. In any case, this loss is due to the friction of moving parts. Friction is a troublesome, but inevitable, consequence of the rotation of a shaft in its bearings. Although friction serves many useful purposes, as for example when power is transmitted through a belt drive, it is the cause of a great waste of power.

No one knows how much power is unnecessarily wasted through friction and otherwise in the industrial plants in this country. Expressed in terms of horsepower, or in dollars and cents, this total loss in power would undoubtedly be larger than most of us realize. As was stated above, a certain loss of power is inevitable in the operation of power drive equipment, but in the great majority of industrial plants there are many places in which power losses that are primarily due to friction can be considerably reduced. It is the purpose of this article to consider some of the ways in which this can be done. Under the competitive conditions that exist today, and with power at its present cost level, serious efforts to reduce power wastes to a minimum can easily be justified.

Frequently, operating executives do not know how much power is being wasted, through friction, in their plants. It is not a difficult matter to check up on this, and the results are almost certain to be interesting and instructive—probably surprising. All that it is necessary to do is to measure the power input to the motor driving a lineshaft, say, with all of the machines running idle. This will give the power loss in the motor, belts, line- and countershaft bearings and so on. If it is desired to determine the loss in the various elements of the system this may be done with equal facility. Thus, for the sake of accuracy the running losses of the motor may be determined by throwing the belt off and measuring the power input to the motor while it is running light. In the same way the power required to drive a lineshaft alone, may be found by throwing off all belts to countershafts, jackshafts and machines. With the data obtained in this way, one is in position to undertake constructive work looking toward the reduction or elimination of some of the power losses. Furthermore, such data make it possible to determine the effectiveness of any change which may be made for this purpose.

Individual motor drive is frequently advocated as a means of eliminating the power losses incidental to the operation of group drives. Under many conditions individual drives unquestionably offer a number of worth-while advantages and are worthy of consideration, particularly in the case of new installations or where extensive alterations to, or revamping of, an existing installation is necessary. However, in many cases, it is not desirable, or feasible, to adopt individual drives for all production equipment, and the operating executive must allow the power drive equipment to remain in substantially its present form. His only recourse is then to reduce friction losses to the lowest point by putting the power drive equipment in the best possible condition.

Beginning with the lineshaft, misalignment of this is a very common and important source of power losses. Granting that the lineshaft was properly erected and aligned at first, settling of the floors and foundation and warping of beams in mill-type



This rope imposes severe operating conditions on the shaft bearings.

Fafnir ball bearings are used in this high-speed drive to a woodworking machine for making plow handles, in the plant of the B. F. Avery Co., Louisville, Ky.

buildings almost always takes place, with the result that the lineshaft is thrown out of alignment. This will increase considerably the friction in the bearings and may cause whipping or bending of the shaft.

It is, consequently highly advisable to check lineshafts for alignment at intervals of a year or so. There are several methods of doing this, one of which was described in the article entitled "Erecting and Aligning a Lineshaft Drive," on page 398 of the September, 1926, issue of INDUSTRIAL ENGINEER. Briefly, the procedure is as follows:

The shaft is leveled with a level having a V-base, by adjusting the vertical screws in the hangers. A strong cord line is then stretched parallel to the shaft and fastened to targets, which may consist of boards nailed to the joists. One target should be nailed firmly, while the other may be fastened by a single nail and then adjusted so that the distance from the line to the shaft is the same at each end before it is fastened securely. The next step is to see that the distance from the line to the shaft is the same at all hangers. After the vertical and side adjusting screws in the hangers have been adjusted and tightened, the shaft should be carefully checked again with the level and with the line.

Nor are the harmful effects of misalignment confined to lineshafts. Gear and chain drives often get out of line, which increases friction losses and wear on the parts.

Ball and roller bearings are widely used on lineshafts and are a very effective means of reducing the friction. There are on the market a number of makes of both ball and roller bearings that can be used to replace plain, babbitted bearings, without much trouble or expense for installation. One of the incidental, but important advantages that accrue from the use of ball or roller bearings is the decided reduction in maintenance expense. These bearings require greasing a few times a year at the most, instead of daily, or at very frequent intervals, as is the case with plain bearings.

The use of ball and roller bearings on lineshafts was discussed, and some of the types available illustrated in an article on page 229 of the May, 1924, issue.

Here is a short-center belt drive in which the pulley ratio is 1:30.

The motor pulley is only 2 in. in diameter, whereas the driven pulley is 60 in. A Pulmax drive (Bird Machine Co.) is used on this installation, which is located in a paper box factory.

Much can oftentimes be accomplished in the way of reducing friction losses by eliminating as many jack- and countershafts as possible and driving the production machines through clutches or clutch pulleys. A good deal of power may be wasted in countershafts, unless these are equipped with anti-friction bearings, while loose pulleys are frequently a prolific source of trouble. Furthermore, constant shifting is hard on belts. Belts subjected to much shifting usually run out of true, sufficiently so that one edge and sometimes both come into contact with the shifting lever, with the result that the belt is eventually badly frayed. This condition is oftentimes responsible for the destruction of a belt long before it has given the service which it really is capable of giving. Many production machines are now equipped with cluch pulleys as an integral part.

Again, much power may be wasted by running groups of machines, or lineshafts, that are not actually in use, for example, when only a portion of a department is working, as on night shifts or at certain seasons of the year.

Under these conditions friction cutoff couplings and clutches can be used to enable a section of shafting or a machine to be disconnected or connected at will by moving a lever. A friction cutoff coupling is ordinarily used to connect and cut off two sections of shafting. One-half of the coupling is usually keyed solidly to one shaft while the other half is keyed either solidly or by a feather key to the other shaft. By different mechanical means such as a lever, toggles, springs, spiral gears and other devices, one-half of the coupling is made to seize and clamp the other half. The friction clamping devices of clutches and cutoff couplings are quite similar in several types, particularly when one concern manufactures both cutoff couplings and clutches. In several such types half of the clutch is keyed on the shaft and the other half fastened to a loose pulley or gear which may ride on the shaft or ride on a special sleeve or extended hub. Clamping action is usually secured by a lever. In reality, cutoff couplings and clutches differ but little in principles of construction other than is made necessary by the different uses.

In this instance roller bearings are used on all of the lineshafts.

This is the light punch press department in a large automobile plant. Hyatt roller bearings are used in the lineshaft hangers.

Inasmuch as mistakes are sometimes made in selecting a clutch of the proper capacity, it may be well to say that perhaps the best general rule to apply in the selection of a clutch is to use one with the full rated capacity of the pulley to which it is connected at the rated speed, or of a double belt of the proper width for the pulley. Another reason for installing a clutch of the full rated capacity of the pulley which it may be called upon to drive, is that manufacturers frequently under-specify the power required to drive their machines; also, when the clutch is mounted on the lineshaft, in particular, additional or larger machines may be added at any time. For this reason, for a lineshaft cutoff coupling it is always well to install a coupling of the full capacity of the lineshaft. It is also advisable when figuring the horsepower rating of a friction clutch or coupling, to take into consideration the effect of suddenly applied loads and the running speed, rather than simply the power transmitted through the clutch when engaged. Obviously, there is much more slippage when engaging a clutch on a fast-running shaft than on a slow-speed shaft. This, of course, affects the life of the friction surfaces.

Other important points to be considered in the selection and operation of clutches and cutoff couplings are discussed in articles in the January and March, 1924, issues of INDUSTRIAL ENGINEER.

Unless properly laid out, short-center belt drives are frequently troublesome from several standpoints, among which are the difficulty of obtaining sufficient arc of contact on the pulleys, and the consequent necessity of using high belt tension to prevent slipping. High belt tension, in turn, greatly increases friction, thus wasting power, causes bearings to run hot, and may cause them to burn out. In addition, excessive tension is injurious to a belt and will tend to shorten its life.

As a remedy for these conditions, wide use is made of idlers or belt tighteners. Oftentimes these idlers are home made from parts that are available at the moment, and do not give the same quality of service that can be obtained from a properly designed idler, of which there are several different makes on the market.

There are two general types of idlers employed to tighten belts. One general type consists of a pulley which may be moved up and down, horizontally, or on a slant by a screw, or rack and pinion. Means are usually provided for locking the idler pulley in position, so that it will maintain a certain tension. With this type there is no means of determining the tension applied to the belt, with the consequent danger that excessive tension will be used. Furthermore, any regulation of tension to meet changing conditions must be made manually. In another common type of idler, use is made of an idler pulley on a swinging arm, tension being maintained by means of counterweights or by springs.

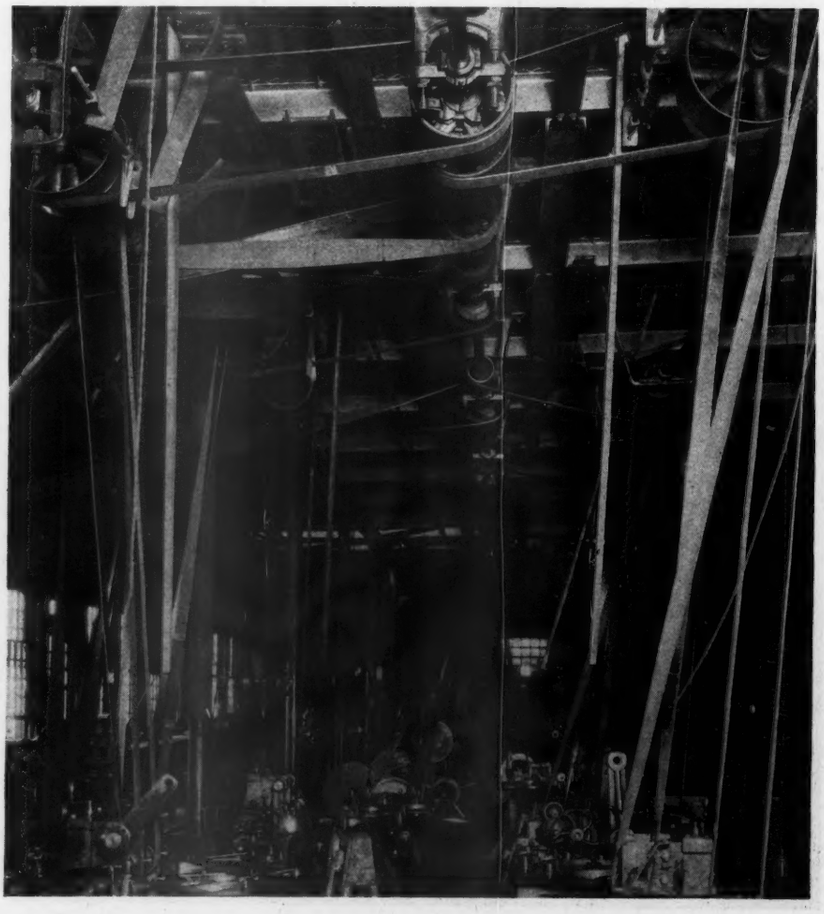
In the use of home-made idlers, particularly, the mistake is often made of placing the idler so that it serves merely to increase belt tension, without materially increasing the arc of contact on the pulley. On the other hand, increasing the arc of contact, which means putting more of the belt in contact with the pulleys, tends to eliminate belt slippage so that a lower belt tension can be used. This in turn reduces wear and tear on the belt and saves power by lessening the friction in the bearings.

Other points which should be kept in mind when using an idler or belt tightener on a short-center drive are: (1) Care must be taken to see that the belt is not put under too high tension. (2) The idler pulley must not be too small for the thickness of the belt used. (3) It is advisable to use a cemented, endless belt. In any case, the belt joint must present a smooth surface on both sides of the belt.

Short-center belt drives possess several advantages and when properly laid out can be made to operate very satisfactorily.

When making a survey of a plant for the purpose of reducing the losses in power drive equipment one should not lose sight of the fact that the care which belts receive has a good deal to do with their efficiency. A belt which is harsh or dry and glazed will have more tendency to slip then will a belt which is soft and pliable and presents a good frictional surface to the pulleys. When it is found that a belt is slipping there is a natural tendency to conclude that the

Ball bearings reduce the power required to turn these lineshafts.
This shows one of the departments in the plant of E. C. Atkins & Co. at Indianapolis, Ind., in which the lineshafts are equipped with SKF ball bearings.

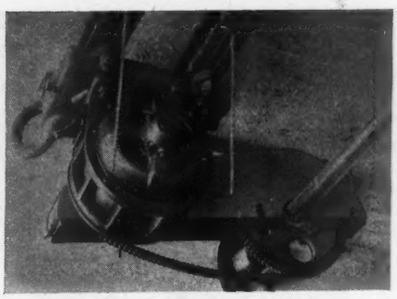


belt tension is too low. Tightening the belt may help to prevent slipping, but it also increases the pressure and consequently the friction in the bearings. Likewise, there is a decided danger of stretching the belt beyond its elastic limit, thus decreasing both its life and efficiency.

As another possible remedy the use of excessive amounts of belt dressing is resorted to. If the dressing is a home-made concoction, as is often the case, there is a fair chance that it will be injurious in one way or another. The care of belts is discussed in the article on page 464 of this issue. Consequently it need not be considered here, except to say that if a belt is of good quality, is of the proper width and thickness for the drive, and is kept clean and in good condition, it can be depended upon to render the service expected of it without putting it under a tension greater than is sanctioned by good practice.

Chain drives may also be employed to advantage when the distances between centers of the driving and driven shafts is short. One of the advantages of a chain drive, which in some installations is of considerable importance, is that there is no slippage, as in the case of belts. With a chain drive every revolution of the driver means a definite number of revolutions of the driven shaft or wheel, according to the speed reduction ratio, and this ratio is maintained continuously, until the drive is worn out.

In general, there are three types of chains employed in power transmission work: block, roller and what are known as silent chains. Block and roller chains are most often used for connecting up two or more shafts of a machine to give a positive ratio between them. Block chains are seldom used for power transmission of over a few horsepower, but are frequently employed on small machines. Well-designed roller chains are used commonly up to about 25 to 30 hp., and in some cases much higher.



Power is transmitted from this 10-hp. motor to the lineshaft through a chain drive.

A double, Diamond High Speed chain operating on 30-in. centers, and giving a reduction of 4:1 is used on this installation in a Southern cotton mill. The lineshaft drives nine duck looms. In this illustration the lower part of the case has been removed to show the chain.

Block chains consist of a solid link joined by a pin and side plates. The pitch of a block chain is the distance from the center of one tooth opening to the center of the next or, as it is most often measured, from the center of one pin to the corresponding pin in the next link.

Roller chains consist of links or plates fastened together by pins fitted through rollers, although some cheap grades are fastened by pins only and are not adapted to high speed or heavy service. In most roller chains the links are of equal length; consequently, the pitch, the distance from pin to pin, is approximately one-half of that of block chains of corresponding size of links which have twice the pitch. For this reason, a sprocket for a roller chain has twice as many teeth as a sprocket for a block chain of twice the pitch.

Silent chains are made up of special types of pins, connecting links so designed as to provide on the chain a tooth which fits into the tooth on the sprocket. They are in reality flexible racks; when straight, as in between sprockets, a chain acts as a rack and when passing over a sprocket acts as a reflex gear. It is similar in effect to two gears with about half their teeth in mesh except that the load is divided among them instead of being all on one tooth, as is the case with gears. The pitch of silent chains is the distance between the centers of pins in a chain. Sprockets do not have pitch dimensions, as do gears, but are designed to take chains of a certain pitch.

As is the case with other types of equipment, chain drives must be properly selected, installed, and cared for if the full benefit of the advantages which they offer is to be obtained. Properly-designed chain drives that are correctly installed and kept in good condition will operate quietly and efficiently, but if they are neglected or abused in any way, their life and efficiency will be reduced. In particular, attention should be paid to the lubrication of chain drives.

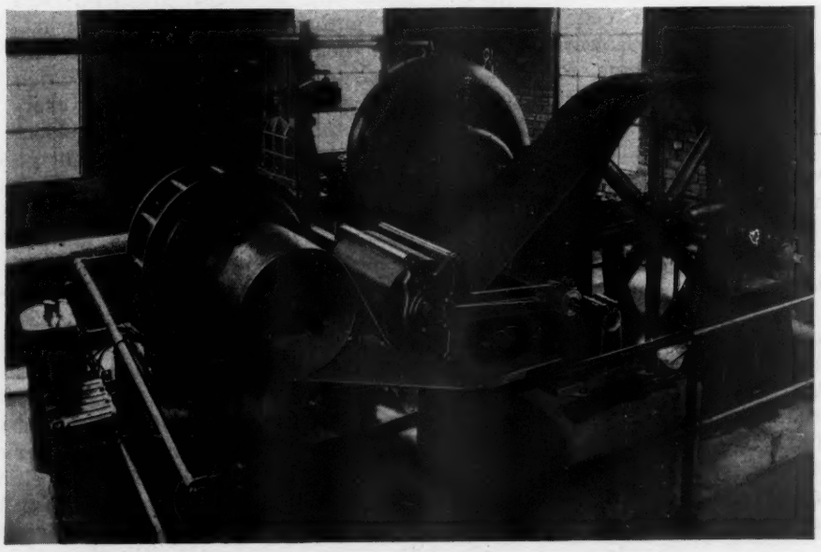
The manufacturers of block and roller chains, and of most silent chain drives, recommend that the chains be run in an oil bath, if the load is heavy or the chain is in continous operation. The wear on chains comes on the pins, between the chain and the teeth. There is also wear due to the rubbing of the sides of the links against each other in the constant bending and straightening out as the chain passes over the sprocket.

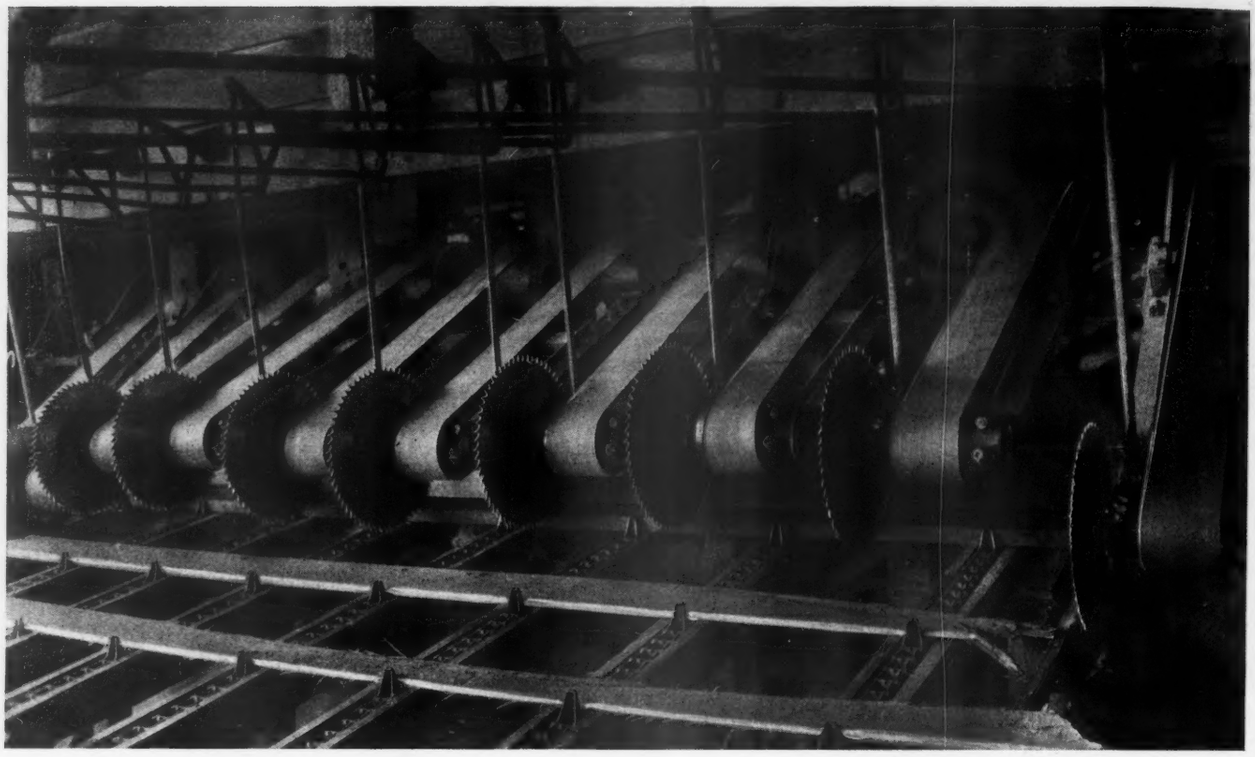
One important advantage that comes from the use of an oil bath is that all of the points where wear occurs are well lubricated. However, grease is frequently used on block

(*Please turn to page 481*)

In this installation the belt speed at times exceeds 6,000 f.p.m., 200 hp. being transmitted at this speed.

The turbo-volute pump shown here is in service in the Hillview Levee and Drainage District, Hillview, Ill. A two-arm, opposed Lenix drive is used to maintain the proper tension on the belt and increase the arc of contact on the motor pulley. The driving belt is 22 in. wide.





Sawmill service imposes severe operating conditions which are well handled with belt drives. Here leather belts are used to drive each trimmer head at the W. T. Brown & Sons Lumber Company, Fayette, Ala. Lumber mills are large users of leather belts.

Recommendations on the

Application and Care of Leather Belt Drives

for industrial plant service, with a discussion of the factors that should be considered in the purchase and installation of this equipment

By J. R. HOPKINS

Chicago Belting Co., Chicago, Ill.

POWER-TRANSMISSION engineers in industrial plants frequently exercise great care in writing their specifications for shafting, hangers, hanger boxes, motors and machines, so as to obtain the most efficient equipment available, and will fight hard to frustrate any attempt to substitute other equipment merely to gain a price consideration, if it means a lowering of their standards of quality, efficiency, and serviceability. However, to many of these engineers, "a belt is a belt," and they requisition it by stating the length, width, and ply required, which gives the purchasing department a free hand to buy on price only.

The following example shows the fallacy of such an arrangement. The best grade of 4-in., heavy, single belt for, say, a $1,500 machine tool would cost about $24. Another belt of the same weight could be bought for about 10 per cent less, or a saving of $2.40. However, the output of the machine tool depends upon the power transmitted to it by the belt. In other words, the output of this $1,500 machine is jeopardized through the $2.40 saving on the belt, which is about ⅛ of 1 per cent of the cost of the machine and probably less than an hour's operating value.

A purchasing agent does not originate a purchase, but in many plants his only restriction when purchasing belting is the quantity needed of the different widths and plies. In many plants he is doing his work well. Purchasing agents have changed in recent years. Today they are more studious, more capable of being entrusted with technical purchases, and are of a higher grade generally. Few purchasing agents, however, know much about the severe requirements or on what machines the belts they buy are to go.

On the other hand, the engineer who has charge of the power transmission equipment, whether he is the electrical engineer, the master mechanic, or superintendent, has the authority to requisition whatever belting he wants. He could specify the belts and do a good job of it and be better off if he exercised that power; but he seldom does. As a rule he lets this right go by default because he fails to appreciate the importance of good belting in his transmission system.

Electrical power costs from $30 to $40 per year per horsepower. The power for a machine using 24 hp. and operating with a 4-in. belt costs $720 per year. The belt costs but $24. A saving of 10 per cent on the belt is only $2.40 on the first cost, which is less than ⅛ of 1 per cent of the power bill for that belt for a year. The average life of an oak-tanned leather belt is well over

8 yr. The power which the 4-in. belt transmits in 8 yr. costs not less than $5,760; so why save the $2.40? The cheaper belt may use at least 1 per cent more power because it may have to be put on the pulleys at a higher tension and use that much more power in the bearings, which would mean that during the life of the belt, the original saving of $2.40 would be responsible for a loss of $57.60 (1 per cent of the power bill), or more than twice the cost of an entire belt of first-class material.

A belt purchased at a saving of 10 per cent in first cost may cause extra shutdowns or require taking up more often and have to be replaced sooner. If shutdowns always occurred after the power was off it would not be so bad, but shutdowns usually come during productive hours and the men have to stand around and wait until the shop starts up again. So why should men in charge of power transmission not make it their duty to at least help out in the selection of leather belting? It is not necessary to take the buying power out of the hands of the purchasing department. However, it is to the advantage of the operating men to co-operate with the purchasing department and give them the benefit of their experience and knowledge. Purchasing agents are professional buyers; that is their job and they should do the buying.

The Responsibility for Belting Should Rest on One Man

The best way to handle the belting problem in any factory is to have one man in charge of the belting. It is desirable to have him and his assistants spend from one to three days in a good belt factory. In this way he can learn how to make laps, how to dress the belts, and how to make repairs. By seeing how belts are made he will have a better understanding of what he is doing and how to do it.

The belt man should requisition, install, take care of, and repair all the belts in the factory. If the plant does not have enough belts to occupy the time of one man he can take on other activities with his belt work. However, regardless of the number of belts, one man should be made responsible. If there are too many belts for one man he should have as many assistants as he needs. The belt man should have a shop or a bench where he can repair belts and do such other work as is necessary. The shop should be equipped with a bench and a handpress, and the man should be provided with the equipment listed in the box on page 468.

Belt Record—Card records should be kept of the performance of all belts. Suitable cards may be secured from belting manufacturers without charge. The card record should be kept on file in the office of whoever has charge of power transmission, where it will be available at any time. Each belt should have a separate card with spaces for a description of the drive and of the belt, when it had to be tightened, cleaned, dressed, the length of life of the belt, and why it failed. The purpose of the card record is to determine whether a belt is the best one for a particular drive, the merits of one manufacturer's belt compared with another, and the amount of care required by a belt. This information will assist in future purchases and will show how to correct present installations.

The belt man should watch the record of his belts on these cards, to see if any are stretching too rapidly or are requiring too frequent dressings and repairs. This will help him to correct unsatisfactory conditions. An oak-tanned belt should last for many years and if it has a short life, either the drive or the belt is at fault. Just before a belt is worn out and taken off, its record should be examined and before putting another belt on the drive, the belt man should decide whether any change in the machine or the type and size of the belt can be made to improve conditions.

Economy in the Use of Belting—The most important factor in true belt economy is to have the proper belt for every drive; that is a fundamental rule and should be followed religiously. The best way to determine this is to keep a card record over a period of years of the performance of all belts. Until such time as information is available from such records it is best to take the advice of reputable belting manufacturers regarding the belts and their reliability under operating conditions. The following points should be borne in mind in ordering a leather belt: (1) Tannage; (2) whether or not it is to be waterproof; (3) the number of plies; (4) width; (5) thickness; and (6) method of running—whether

This record card gives all of the data that should be known about a belt drive application.

Compliments of
Chicago Belting Company
Manufacturers of Leather Belting

Belt No.
Dept:

BELT RECORD

Mill No. Record made by

LOCATION	Date put on / Date taken off
	Life of Belt
Drives	Tension lbs. per sq. in. of Section
Length over Pulleys / Cut to	Is Tight Side Top or Bottom / H. P.
Width / Thickness / Ply	Crossed or Open
How Fastened	Cost of Belts
Pulleys-Driver D. F. R. P. M. to	Cost of Maintenance
Driven D. F. R. P. M. Vel. F. P. M.	Total Cost
Maker / Kind of Belt	Cost of New Belt

Date Taken Up	Amount Taken Out	Workman's Name	Time Repaired	Cost of Labor		REMARKS

MAKER	KIND OF BELT	SIZE	CUT TO	COST OF BELT	DATE PUT ON	DATE TAKEN OFF	LIFE OF BELT

Nothing takes the place of Leather

open, crossed, shifted, quarter-turn, and so on.

Tannage — Oak-tanned is the cheapest leather belt, will last the longest, and is recommended to be used wherever possible. Where moisture, steam or heat, or where considerable humidity comes in contact with the belt, and such a condition cannot be avoided, waterproof oak-tanned leather belting is recommended. Chrome-tanned belts are used where there are excessive heat conditions, excessive steam, acid fumes, or on very high speeds over small pulleys. Oak-tanned belts can be used to operate under heat conditions up to 135 deg. F., while chrome-tanned belts will stand heat up to 250 deg. F. All belts should be ordered with waterproof cement unless there is no moisture whatsoever to contend with.

Combination-tanned (so called because of the combination mineral and vegetable tanning process) leather belts are made essentially for use where the belts operate over three or more pulleys. Both chrome- and combination-tanned belts are more expensive than oak-tanned belts. It is important that all belts be made up with waterproof cement if they are to be used in a damp place, as moisture coming in contact with the ordinary cement causes it to soften and the laps and plies will soon open up.

Number of Plies—Practical rules to be used when deciding how many plies of leather to use are as follows: (1) Single belts should not be used over 8 in. wide. (2) Double belts should be used only on pulleys 6 in. in diameter and over. If it is necessary to use a double belt on a pulley smaller than 6 in. an especially pliable belt should be ordered; otherwise there is too much bending strain for the thickness. (3) Three-ply belts can be safely used on pulleys 20 in. in diameter and over.

Things to Do to Get the Most from Belts

Men who are in charge of power transmission should:
Initiate the purchase of leather belts.
Have a belt man responsible for all belts.
Supply him with equipment necessary.
Make as many belts as possible endless by cementing the ends.
Inspect the belts regularly.
Secure open laps regularly.
Dress the belts systematically and at regular intervals.
Keep belt record cards.
Watch these belt cards.
See that the right belt is on each pulley.
If the belt now in use is too light for the load, put on a heavier one.
Know what makes a good leather belt.
Know how to buy it intelligently.
Remember: An ounce of preservation is worth ten pounds of cure in belt operation.

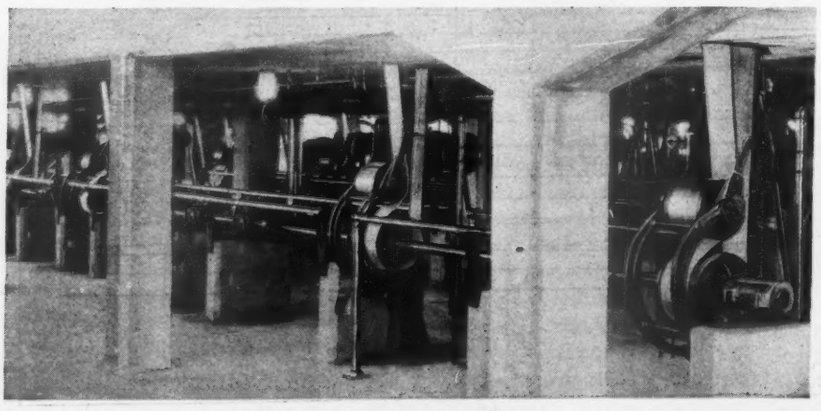
It is best to use a double belt wherever possible on step-cone pulleys and shifter drives. A single belt does not have the thickness to stand shifting and the area of the edge that comes against the shifter is not great enough to keep the belt from curling. Never use a chrome or combination-tanned belt with a shifter; only oak-tanned belts should be used for these drives.

Length — When specifying length it is important to understand what is meant by endless belts. An endless belt is one that has its ends scarfed and cemented together. This method gives a joint practically as strong as the leather itself and is much superior to any joint in which fasteners are used. Fasteners or a lace makes holes in the leather and every hole in a leather belt reduces the tensile strength of the belt in direct proportion to the size of the hole. If a belt has a tensile strength of 800 lb. per inch of width, a ¼-in. hole will reduce the tensile strength 200 lb. In addition, fasteners and lace bump as they go around the pulleys and belts so fastened, if they do break, usually break where fastened.

All belts that can be made endless should be so joined. If a belt is to be made endless, the length around the pulley should be measured with a steel tape and the amount needed for the lap should be *added* to this. When ordering a belt from a belting company or storeroom it is safe to *deduct* ⅛ in. per foot in length from the total length required. This is to allow for the amount the belt will stretch when drawn up on the pulley.

The belt should always be cut with square ends and it is best to use a carpenters' square as a guide for the knife. When ordering a special belt the following information as to length, measured by a steel tape, is required: (1) State on all requisitions, "Actual tape length around the pulley, with no allowance for stretch." (2) If a belt is to be made endless by the manufacturer state on requisition, "To be made endless, length does not include lap." (3) If the belt is to be made endless by the user after it has been put around the pulley, state on the requisition, "One end scarfed, length does not include lap." (4) If the belt is to be put together with lace or fasteners, state on the requisition, "Square ends."

Width—The width of the belt is, of course, limited by the face of the pulley. All pulleys should be at least ½ in. wider than the width of the belt. Frequently installations are found where the belt is too narrow to deliver the load because it is limited by the width of the pulley face. In such cases a heavier belt, or a belt with an additional ply should be tried. If the pulley is still too small for the heavier belt the drive should be changed so that the pulley will be wide enough for the belt or the diameter of both pul-



This lineshaft drives a large paper machine on the floor above.

In this case all of the drive belts operate from a single lineshaft. Sometimes a carefully synchronized motor is placed at each belt. On a paper machine, belts are frequently used to obtain sufficient flexibility to take care of the different grades of paper and the different speeds of the paper machine. This installation is located in the plant of the Crown Willamette Paper Company, Oregon City, Ore.

leys increased to give a higher belt speed and the narrow belt used.

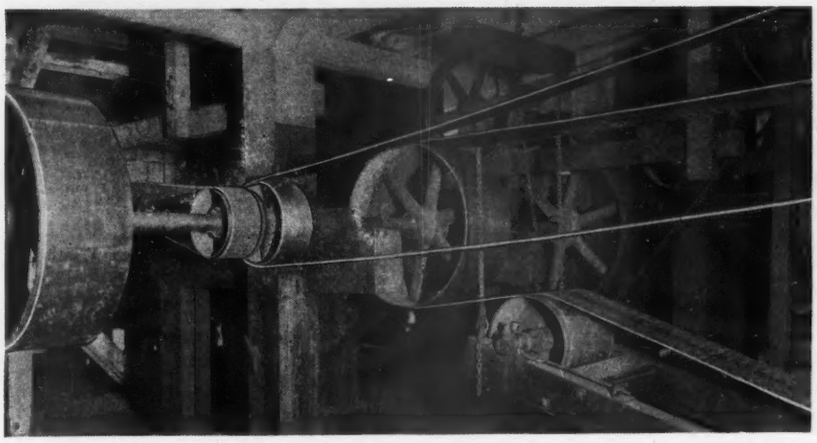
Length, width, and horsepower complications may be computed on a celluloid slide rule scale, which is furnished by The Leather Belting Exchange through its member companies. This slide rule is free on request.

Making Leather Belts Endless—Complete printed instructions for making leather belts endless are obtainable from leather belting manufacturers. These instructions are illustrated so that an ordinary workman with very little practice can become reasonably expert in making leather belts endless. Belts made with non-waterproof cement require only about 5 min. in which to dry. Belts made with waterproof cement require two coats, the first of which has to dry from 20 to 30 min. and the second of which has to remain in the belt press a similar length of time. For these reasons it is best to allow at least 1 hr. for making a waterproof leather belt endless.

Always place the hair or grain side of the belt against the pulley because the grain side transmits from 40 to 60 per cent more power than the flesh side. There are no exceptions to this rule, for running single belts. All belts should be run in the direction of the arrow which is stamped on the belt. This is so that the feather edge of the lap on the side next to the pulley will point away from the pulley as the lap approaches it.

Proper tension for putting on leather belts is 36 lb. per inch of width, per ply, per strand (every belt has two strands). A high-grade leather belt shortened ½ in. per foot in length and then drawn together will have approximately this tension. On a belt that is well stretched, future take-ups often can be eliminated by putting on the belt as tight as is possible. The majority of belts are put on too loose. The belt should be put on as tight as is possible without too much strain on the bearings, lineshaft and hangers.

Belt Cement—Always use a belt cement made by a high-grade leather belting manufacturer; never use carpenters' glue, as it is not suitable. When using ordinary belt cement it should be heated to a temperature of 167 deg. F. Do not heat up any more cement than will be used at one time, as it deteriorates on standing. If the weather is cold the leather should be warmed slightly by lighting paper and passing it over the parts to be cemented; otherwise the glue may cool before the ends can be cemented together because non-waterproof cement cools quickly. It is important that belt laps be brought together squarely and quickly after the cement is applied.



This belt drive is in the basement of the plant of the Good Pine Lumber Company, Good Pine, La.

Here a single lineshaft transmits the power through belts to machines on the floor above. The efficiency of such a lineshaft with modern bearings and the best leather belting is equaled only by large electric motors operating at full load. In many cases a higher efficiency can be obtained with mechanical power transmission equipment than with electrical.

After cementing, the laps should be rubbed down well with a smooth edge of a scraper and, if on a large belt, hammered for several minutes so that all air will be expelled from the joint. Although non-waterproof cement sets quickly, the belt should be allowed to stand as long as possible. It is good practice to permit newly cemented belts to stand from 3 to 6 hr. before using them. It is best to make a rule that a belt should never be placed on the pulley until at least 1 hr. after cementing and this soon only in emergencies. In hot or damp weather more time is required for the cement to set than when the weather is cool and dry.

After a belt has been taken off the pulley to be shortened or repaired a light coat of liquid belt dressing should be applied before it is returned to the pulley.

Belts that are to be put on with fasteners should have the ends squared carefully. The two ends are drawn up with the clamps in the same manner as when making endless belt. The two ends will overlap and the amount to cut out is marked on one end. This allowance should take into account the space taken up by the fasteners. The belt is then taken down from the pulley, cut to the exact length, and the fasteners applied. Rawhide laces are not widely used except on hand-shifted belts. As was stated earlier in this article, endless belts should be used wherever possible, as the holes required for lacing or other forms of fasteners weaken the belt.

Retightening Belts—Belts stretch more when new than after being used for some time and so it becomes necessary to tighten them to maintain the proper tension. The best stretched leather belting will not require more than one or two take-ups and after the stretch is all removed by actual running service no more take-ups will be necessary. Usually belts require tightening about three days after being put on. If a second tightening is necessary it usually comes about a month later than that. All belts should be inspected and whenever they appear to be too loose to do the work, should be tightened. Retightening or taking up a belt requires a little time, but it is well spent. When putting on a new belt, do not be afraid of putting it on too tight.

Examination During Service—Belting and drives should be inspected at regular intervals by the belt man; an examination of the card record will show when the inspection should be made. At these times the belt should be examined carefully. Once every two or three months should be sufficient for most belts, but between times the belt man should be on the lookout for trouble from unexpected sources. Dressing and cleaning the belt can be attended to as a part of the regular inspection.

Some of the points to look for and to do during the examination of a belt are as follows: If a belt lap starts to open up cement it down at once; don't wait for the belt to break. If a belt becomes dry, see that it is dressed. Have a regular plan for dressing belts periodically. It takes less time to do that than to do one repair job. Also, it requires less thought on the part of the belt man. If a piece of machinery or anything else rubs against a belt, remove whatever is doing the rubbing; otherwise it will wear out the belt. If a belt is operating under a condition where oil is constantly dropping on it, correct the condition. It is much more effective to stop the dripping oil than it is to try out belt after belt to try to get one that will run under such a bad condition.

Belt Dressing—Belt dressing still seems to be one subject on which most belt users want information. Leather belts should be dressed periodically every six months for the first year and at least every three months afterward. Belt dressing should never be of the sticky type as this destroys the belt. The best stick dressing today will stop slip instantly and also is good for the belt and prolongs its life.

Do not use castor oil or neatsfoot oil because they do not stop slip. A belt dressing that simply makes the belt pliable and does not stop slip instantly will not keep up production. The best belt dressing in either stick or paste form does not cost much and a comparatively small amount of dressing will keep a number of belts in good condition for a year.

Use a belt dressing that will penetrate the leather, as it is the interior fibers that need lubrication the most. Many belt dressings are surface dressings only. When applying a dressing spread on only as much as the leather will absorb. Do not put the dressing on too hurriedly, as it will tend to make the belt slip until the leather has absorbed it. Put on a little and then the slipping, if there is any slipping, will stop instantly. Then apply a little more at a time, several times if necessary. With all belt dressings be careful not to put on too much. It is better to put on too little than too much.

Many power maintenance men have only a smattering of knowledge of how to buy good leather belting and of what there is about belting that makes one leather belt last 10 yr. with only one take-up, while another may last only 5 yr. and have a take-up every year on the same drive. There is a great difference in the quality of leather belting. Any man who will take the simple steps to assure himself that he is buying the best leather belting, will secure results that will reward him amply for the time spent in a little study of the subject.

Later on, if not right now, his opinion may be asked as to the relative merits of group and individual drives for some one of his shops. If he knows that leather belting can be secured that lasts for years with less than 1½ per cent slip and frequently less than 1 per cent, he can understand why a group drive of five belts driven by one 12-hp. motor may be better than, or at least entitled to consideration as a competitor of, five individual motors of 5 hp. each.

Equipment Needed by Belt Men

Belt clamps for putting on and retightening belts.
Electric gluepot and heater.
Glue brush.
Waterproof cement.
Non-waterproof cement.
Heel shaver, scraper and steel for sharpening same.
Belt knife, steel square.
Opening hammer.
Steel measuring tape.
Belt lacing equipment and supplies.

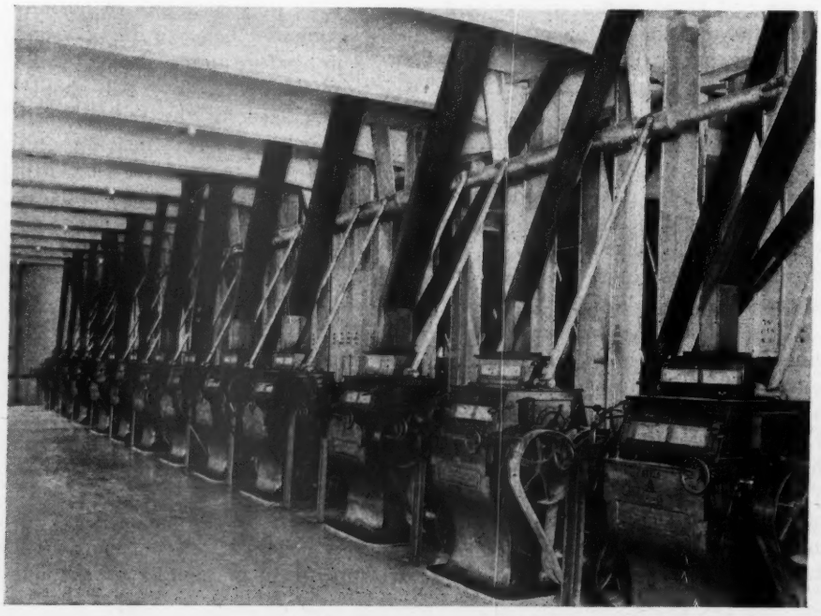
This list contains the essential items of equipment. Other tools and supplies may be added as the work increases.

Some Recent Improvements in Leather Belting

To understand why leather belts are so efficient it is necessary to appreciate the improvements that have been made in leather belting in recent years. Today the best leather belting has a much improved surface. This is measured by the increase in the adhesion of the surface of the belt to the pulley face, which is a very important item in power transmission because the coefficient of friction of a belt is dependent on its pulley grip and its tension. The more a belt grips the pulley, the less tension is required. Where less tension is required, less power is used, because the power a belt will transmit is the difference between the tensions on the tight and loose sides. For this reason the adhesion of a leather belt is important. However, how many belt buyers can tell the adhesion factor of new belts coming into their plant?

Stretch in leather belts has also been improved in that some leather belts of today have about one-third less stretch than the best leather belts of 10 yr. ago. The best leather belting, from a maintenance point of view, is that which requires the fewest take-ups. Today, belting can be obtained that requires but one or two take-ups at the most. There is also a stretchless type of

(Please turn to page 486.)



This line of rolls in a flour mill at the Kansas City Flour Mills, Kansas City, Mo., is operated from a line-shaft on the floor below.

Push-button control of motors is becoming more widely used in industrial applications. This installation of automatic compensators is operated from push buttons located at the individual machines. These compensators were made by the Industrial Controller Co.

"What Controller Should I Use for This Drive?"

By ARTHUR J. WHITCOMB
Associate Editor, Industrial Engineer

CONTROLLERS are the brains of power drives. They start the motor, stop it, reverse it, govern its acceleration and deceleration as well as its speed and protect it against damage from overload, undervoltage, single-phasing, and the like. Can we, therefore, in laying out power drives that are intended to stand up in severe service afford to slight the selection of the proper set of brains? A man may have a magnificent physique, yet without the proper mental balance his energy will be wasted in misdirected effort. Likewise, the power drive with a poor set of brains, will behave more or less like a lunatic, causing jerky starts, burning contacts, blazing fire at places unexpected by the average workmen and in general causing undue wear and tear on itself, the motor and the mechanical elements of the power drive connected thereto.

Industrial controllers exist in such an astonishing variety of types and forms as to confuse anyone not an expert in this field. The selection of the proper motor for a given service, apart from that of a special nature, is a relatively simple matter and concerns chiefly the power available, the work to be done, and the general conditions surrounding the installation. While this is usually given intelligent study, it is often true that the controller is chosen with less care and understanding. The controller for a motor driving a given machine ordinarily plays a very minor part in the cost of the complete installation, but its failure in any way to maintain service or secure the proper performance from the equipment will quickly counterbalance the false economy, which all too often is the main consideration in its selection.

To apply controllers intelligently to power drives requires a study of what the controller has to do and the various methods of accomplishing such results. Selection of a controller cannot be made by going through a list of the various types available in their countless combinations, but we can bring up one after another of the fundamental considerations and arrive at what we are searching for by a process of elimination.

The first consideration is duty. By this we mean the specific functions which are expected of the controller. These may be listed as follows:

(1) To start and stop the motor, either at fixed points in the cycle of operation or at the beginning and end of operation.

(2) To govern the acceleration and deceleration of the motor and provide proper accelerating and decelerating conditions.

(3) To control the direction of rotation.

(4) To control the speed of rotation.

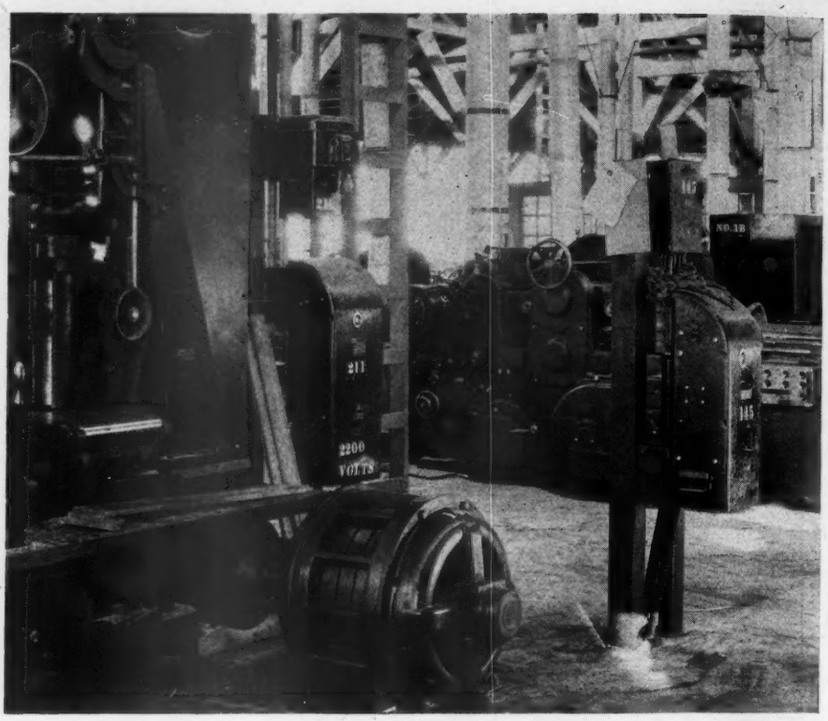
(5) To control the amount and direction of torque, and

(6) To control the flow of current.

The next consideration is service and by this we mean the specific application in which the controller is to be used, which includes: General Purpose, covering occasional starting

The compensator finds wide application for starting squirrel-cage motors.

The two compensators shown here are of General Electric manufacture and are in the plant of the Oregon-American Lumber Co. at Vernonia, Ore. These compensators are manually operated, but are tripped by pushing the button at the top of the compensator.



of motors; and Special Purpose, covering a long list of applications, such as rubber mills, cranes, elevators, steel mills, paper making, and the like, each of which demands some distinctive feature in the control in the way of capacity, specific functions and so on.

Another consideration is protection to motor and driven machine, included in which are overload protection, undervoltage protection, protection against too high current inrush and shock to machinery, protection against overtravel, overspeed protection, and protection against phase reversal, phase failure, and too sudden strengthening of motor field.

A feature that should always receive special consideration is safety to persons. These include protection against restarting of motor after failure of power, without personal intervention; enclosure of live and working parts against shock or burn; locking features to prevent operation of equipment while work is being done in inspecting or repairing; emergency stops to shut down the motor from any given point and to quickly stop it by braking or plugging, and devices to prevent overtravel or overspeed on elevators or other equipment handling dangerous material, such as molten metal.

There are also some conditions surrounding an installation which may require special protection of the controller. In the presence of an atmosphere filled with explosive material, gas, or acid, as in mines or chemical works, it is necessary to protect the controller against corrosion and against ignition of gas by arcs. It is also necessary in many cases to protect the controller from water.

In selecting the controller best suited for the power drive in question, convenience to the operator should not be overlooked. Particularly with machinery in which the work requires constant attention, it is important that the operator find the control within easy reach and manipulated with little care and effort. This brings up the question of whether the control should be of the automatic or manual types.

Having then determined what our controller has to do and what characteristics it must possess, let us consider the various types that are available. Electric controllers may be roughly divided into two general classes: those providing for manual acceleration of the motor and those providing for automatic acceleration. With the first class, the acceleration of the motor is entirely under the control of the operator, while with the second class this operation is performed automatically. An example of the first class is a drum or face-plate controller, while the magnetic controller is a good example of automatic control.

The earlier forms of control were manually operated. They were used on direct-current motors in railway and elevator service. These were very crude, but they have been developed until the modern manual controller is a thoroughly reliable and satisfactory piece of equipment. As compared with the automatic, magnetic type of control it has certain advantages and limitations which should receive due consideration when deciding what type of control is better adapted to the power drive in question.

The manually-operated controller is low in price as compared to the automatic controller, particularly in the small and medium capacities. It is compact, simple, entirely enclosed and can readily be made dustproof, spray-proof or gasproof, if necessary. It is strong mechanically, simple to operate, and easy to inspect.

On the other hand there are certain limitations of manual control that must be remembered when specifying the control for a given job. With the manually-operated controller, the operator must use discretion in not accelerating the motor too rapidly, thereby injuring the motor and driven machine. More trouble is usually experienced with arcing in this type of controller, thereby causing more rapid deterioration of contacts under severe service conditions and necessitating frequent inspection and adjustment of contacts. Also, for large motors there is a limitation in the size of manual controller that may be used, which is often objectionable when space for the master switch or push button station is limited, as on cranes and other applications. Also, the manual controller requires more effort to operate than the corresponding automatic controller, and often requires a separate protective panel to obtain overload and no-voltage protection.

Although automatic control is in general more expensive than manual control, it has many advantages that appeal to the operating executive. Probably the most important of these is the fact that push button control may be used, thereby permitting the use of operators who have no knowledge of electric equipment.

It is more "foolproof" than other types and may be located so as to in nowise endanger the operator. It may be provided with various safety devices. The automatic controller is characterized by positive opening and closing of contacts, which have long life, even though they are cheap and easily renewed. This type of control is strong and rugged, as well as easy to inspect when repairs or maintenance are required.

Also, this type of control permits the location of the master switch or push button at any desired point which may be at some distance from the controller. In other words, a large number of master switches may be located in a control pulpit, thus centralizing the operation of a large number of drives while the controllers may be placed at any convenient location.

However, against these advantages there are several limitations in the use of automatic control as compared with the manual type. Automatic control is more expensive than manual control. Also, the larger sizes occupy considerable space. In general, the wiring diagram is more complicated and requires a higher type of maintenance man to take care of it.

But even with these limitations the use of automatic control is becoming more widespread. The steel industry is a very good example. Many kinds of control have been developed in the heavy-duty service required by this industry. Beginning with crude manual controllers, this industry has progressed to the point where automatic control is almost the rule for the great majority of power drive applications. The main reason for this trend to automatic control in the steel industry is the fact that remote control is obtained by means of automatic control; the control master switches may be centralized, thereby permitting one man to control more operations, and because the control is automatic no consideration need be given the motor by the operator of the control. A feature that has increased the use of automatic control is the fact that better protection is given to equipment; the operator cannot abuse the latter. This is an important point, due to the progressively poorer class of labor that is being used in the mills.

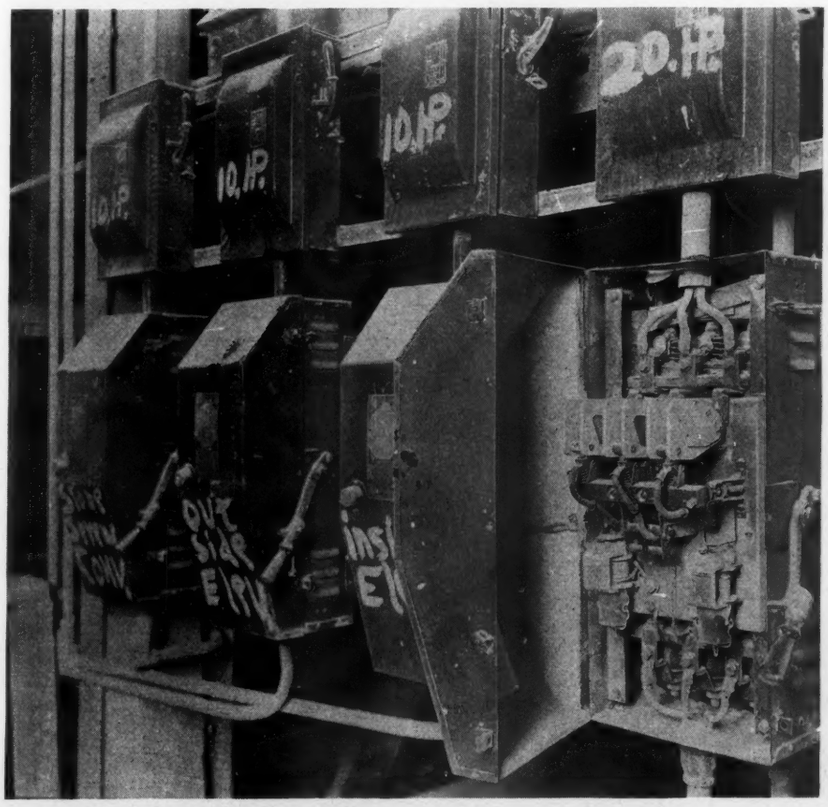
Another factor that is coming to the fore at the present time is the fact that in certain operations where drives must operate in sequence or on a certain cycle, the controls for the various drives may be interlocked so as to start automatically without an operator pushing a button. For this reason the past few years have seen a great reduction in the number of men required to operate a given mill.

Having weighed the relative advantages and limitations of manual and automatic types of control and having decided which type is best suited to the drive under consideration, the next step is to select the proper type of controller for the motor used on the drive in question.

Probably the motor in most common use today is the squirrel-cage induction motor. It is standard practice to start squirrel-cage motors in sizes up to 5 hp. inclusive by connecting them directly across the line by means of some form of starting switch. This same method is also permissible for larger motors providing that the starting duty is light, the driven machine capable of sustaining the sudden shock, and that the current peaks are not objectionable. However, the local public utility usually has some regulations regarding the size of motor that may be connected directly to the lines in this manner and these regulations must be consulted before finally deciding upon this method of control.

When using this method of control an across-the-line starter is used. It may be either manual or automatic. The manual type usually takes the form of a safety switch and is so arranged that the motor is thrown across the line without fuses, or with heavy starting fuses. After the motor comes up to speed the handle is thrown the other way so as to cut in the running fuses which are of the proper size to protect the motor against overload. There is also a manual, across-the-line starter which consists of an oil circuit breaker with definite time-limit, overload relays.

The automatic across-the-line starter consists of a magnetic contactor and some form of overload protection. The contactor is controlled from a push button switch which may be located at any convenient point. The important thing to consider is the type of overload protection provided. Inasmuch as



Another method of starting squirrel-cage motors involves the use of a primary-resistance starter.

These Allen-Bradley, manually-operated, primary-resistance starters are in the plant of the Kosmos Portland Cement Co., Kosmosdale, Ky. Moving the operating handle upwards connects the motor to the line and then by compressing the carbon discs which form the resistance, reduces the resistance to a low value, after which the magnetic contactors close, shorting out the resistance.

the magnetic contactor closes upon pushing the push button and no other connections are made, the overload protection must keep the motor on the line during the period the heavy starting current is taken and yet trip it off the line if an abnormal working load is encountered. This characteristic is provided for in the overload relay by arranging a time delay in the operation of the overload relay through the medium of a dashpot or, more recently, by means of a thermal element which does not operate to trip the motor until it has reached a certain temperature.

To reduce the shock of starting and to prevent line disturbances caused by excessive starting current being drawn, reduced voltage may be applied to squirrel-cage motors by several different forms of controllers. Probably the most common method involves the use of auto-transformers connected across the line with taps running to the motor. Several taps (usually from 50 per cent to 80 per cent) are brought out so that a choice of several starting voltages is obtainable. This type of starter is known as a compensator and can be obtained in both manual and automatic types. The usual manual type is equipped with a double-throw circuit breaker immersed in oil, so that the compensator handle is thrown one way for starting and after the motor comes up to speed, the handle is thrown to the opposite side, which action opens the starting contacts and closes the running contacts. In addition to this the compensator provides no-voltage and overload protection for the motor.

The automatic compensator is very similar to the manual type except that solenoids or magnets are provided for operating the starting and running switches. A definite time relay provides the necessary time interval between closing of the starting switch and closing of the running switch. In one type of automatic compensator, magnetic contactors of the air-break type are used instead of the double-throw, oil switch. This type of controller also uses a thermal overload relay, as well as providing no-voltage protection.

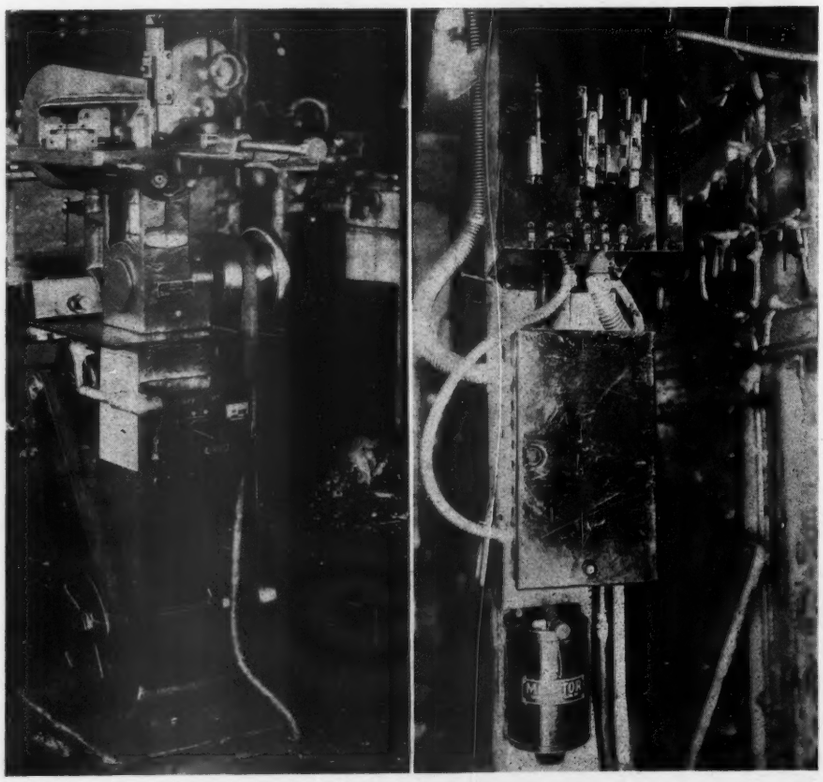
Naturally the automatic compensator is intended for remote control from a push button station that may be located at any desired point. The manual type cannot be arranged for this method of starting, but it can be stopped from a distant point by connecting a push button switch in the no-voltage release circuit. This is often done when one or more emergency stopping stations are necessary and also when the motor must be interlocked with some other drive, such as would be the case with a number of conveyor belts that are in series, one feeding the other.

There are several advantages arising from the use of the compensator or auto-transformer type of starter. Reduction of voltage by transformer action avoids resistance losses, thereby causing a reduction in power for starting. Also, the line current taken in starting is less than the motor current in a degree depending upon the tap used. With a 50 per cent tap, the line current is only half of the current that flows through the motor winding.

Another method of starting squirrel-cage motors, which also meets with favor, involves the reduction of voltage by the insertion of resistance in series with the motor primary The amount of resistance may be adjusted to secure the desired starting voltage and torque. As the motor attains speed the resistors may be cut out in one or more steps. This method differs distinctly from the auto-transformer method in that the latter causes a reduced voltage of constant value to be applied to the motor, whereas the voltage at the terminals of a motor in series with primary resistors varies according to the motor current.

This form of control, which is known as the primary resistance method, is made in both manual and automatic types. One manual type uses tubes containing graphite discs for resistors. Pressure is gradually applied to these discs through a cam operated by a lever, thereby reducing the resistance. Slowly moving this lever from the *off* position to the *on* position connects the motor to the line through resistance and steplessly cuts out the resistance, leaving the motor across the line. The automatic type of starter is more commonly used with this method, however, and many controllers of this type use the cast-iron grid form of resistance with magnetic contactors cutting out one or more steps of it as the motor accelerates. Acceleration is controlled through a definite time relay or by a series relay actuated by the motor current. Overload and no-voltage protection are also provided.

One of the advantages of this method of starting is that it is not necessary to interrupt the circuit in



Across-the-line starters are the simplest form of control for squirrel-cage motors.

In the center illustration is shown a Condit, manually-operated, across-the-line starter while at the right is shown a Monitor automatic across-the-line starter. This one is intended for reversing service on a paper baler and uses a drum reverse switch instead of a push-button switch.

This totally-enclosed synchronous motor controller is used on a motor-generator set.

The large steel tank in the corner adjacent to the d.c. generator contains the automatic compensator that provides reduced voltage for starting and also contains an automatic field switching panel for applying the d.c. field excitation to the synchronous motor. This control equipment was made by the Electric Controller & Mfg. Co. and is installed in an automatic substation. The d.c. generator is controlled from the switchboard shown at the extreme right of the picture and was supplied by the Automatic Reclosing Circuit Breaker Co.

transferring from the starting voltage to line voltage; consequently, interruption of torque is thereby avoided. This type of starter has a low first cost, is quite simple and is easy to repair. It also has a good power factor during the starting period.

Probably the newest type of squirrel-cage motor controller is the primay reactance type in which reactors, in place of resistors, are placed in series with the motor primary, as described in the foregoing. Otherwise it is very similar to the primary resistance type. This type of starter is marked by extreme simplicity and is very easy to adjust for the starting conditions desired.

Four types of controllers for squirrel-cage motors have been described, each of which is made in both manual and automatic types. Bearing in mind the differences outlined in the foregoing, selection should be based upon the characteristics that best fit the conditions on the drive in question. In addition to the foregoing it might be said that the across-the-line starter is the simplest and most reliable form and is preferable wherever conditions permit its use. Where there are limitations as to the permissible shock to the motor or drive, as well as line disturbance, one of the other three types must be chosen. This is usually the case when the motor rating is 10 hp. or larger. The relative advantages and disadvantages of primary resistance controllers and compensators is discussed at greater length in an article entitled "Operating Characteristics of Compensators and Primary Resistance Starters," published in the January, 1926, issue of INDUSTRIAL ENGINEER.

The characterictics of the wound-rotor motor are such that excellent starting performance may be secured by varying a resistance connected in the secondary or rotor circuit of the motor. A controller for this type of motor involves switching in both the primary and secondary circuits. The primary must be connected and disconnected from the lines in starting and stopping the motor and if reversing service is required the primary connections must be reversed. The secondary switching involves cutting out steps of resistance. The controllers for performing both of these functions may be manual or automatic. In the manual type the primary switching is handled by a carbon or oil circuit breaker, or if of low voltage, by some of the contacts of the drum controller or faceplate starter used on the secondary circuit. Where separate control devices are used for the primary and secondary circuits, some form of mechanical or electrical interlock is desirable to insure that the devices be operated in the proper sequence. When reversing service is required on low-voltage motors, a drum controller or faceplate starter handling both the primary and secondary circuits is more commonly used. When a separate primary switch is used, the low-voltage and overload protection are incorporated thereon. When the primary switching is done by the same device handling the secondary circuits, separate overload and no-voltage relays must be provided.

Automatic control for wound-rotor motors involves the use of magnetic contactors. These handle the primary and secondary circuits in proper sequence and also automatically accelerate the motor under the control of accelerating relays. A push button station or a master switch is used for starting and stopping the controller.

In addition to these types of control for the wound-rotor motor there is also the liquid controller utilizing plates immersed in an electrolyte for secondary resistance. This controller will not be described, for in this country it is principally used only on some of the larger sizes of motors.

In deciding which of the foregoing types shall be used on a given drive, consideration must be given to the size of the motor, voltage, and the frequency of starting and stopping. As the automatic controller is more expensive its use can be justified only when frequent starting and stopping are required, high voltage or large capacity handled, or remote control desired. Speed regulation can be obtained with either type of control on wound-rotor motors simply by cutting resistance in or out of the secondary circuit: that is, by stopping on any starting point that gives the required speed under load. In case speed regulation is desired, resistors having sufficient thermal capacity for this duty must be selected, instead of the usual starting-duty resistors.

Practically all present-day synchronous motors are started by applying reduced voltage to the primary or stator winding. As the motor approaches synchronous speed, direct-current power is applied to the field winding and line voltage is applied to the stator winding of the motor. During the starting period it is essential that the d.c. field be closed through resistance so as to prevent the generation of high voltages in the field. Hence the controller for a synchronous motor should provide a means for connecting the motor primary across a reduced voltage and then across line voltage; a means

for connecting the fields across resistance during the starting period and to their direct-current source after the motor has accelerated; a means for adjusting the motor field strength; and instruments and protective features as required.

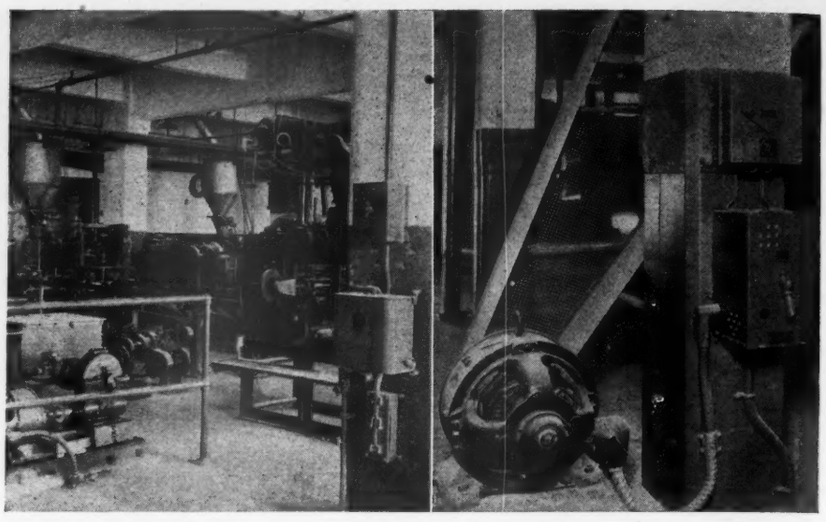
Control for synchronous motors is made in both the manual and automatic types. With the manual type either two oil circuit breakers or a double-throw, oil circuit breaker is used for applying the reduced voltage. A field switch, meters, and field resistors complete the control.

Due to the fact that more care and skill are required in starting a synchronous motor than is the case with a squirrel cage motor, automatic control is often preferred. In this type magnetic contactors or solenoid-operated oil circuit breakers replace the oil switches and a magnetic contactor replaces the field switch. To insure that the various switches close at the proper time a relay working either on the time element method or the field frequency method, or a combination of these methods, governs these functions.

Low-speed synchronous motors can be started by connecting them directly to the line. In such cases the starting kilovolt-amperes are about the same as required for a high-speed synchronous motor started with 65 per cent of line voltage. This type of starter subjects the motor to fewer current peaks, for there is no peak due to transfer from starting voltage to running voltage. When conditions permit line voltage starting, the control equipment is simplified and the number of contactors or circuit breakers is reduced.

The decision as to what type of synchronous motor control to use must be based on the frequency of starting and stopping of the motor, the type of men who will operate it, the motor speed and capacity, cost, and the character of the load that the motor will have to start.

In the foregoing we have briefly treated the different types of alternating-current motor control with the exception of those used on single-phase motors. These will not be included in this article. Let us now consider the various types of direct-current controllers.



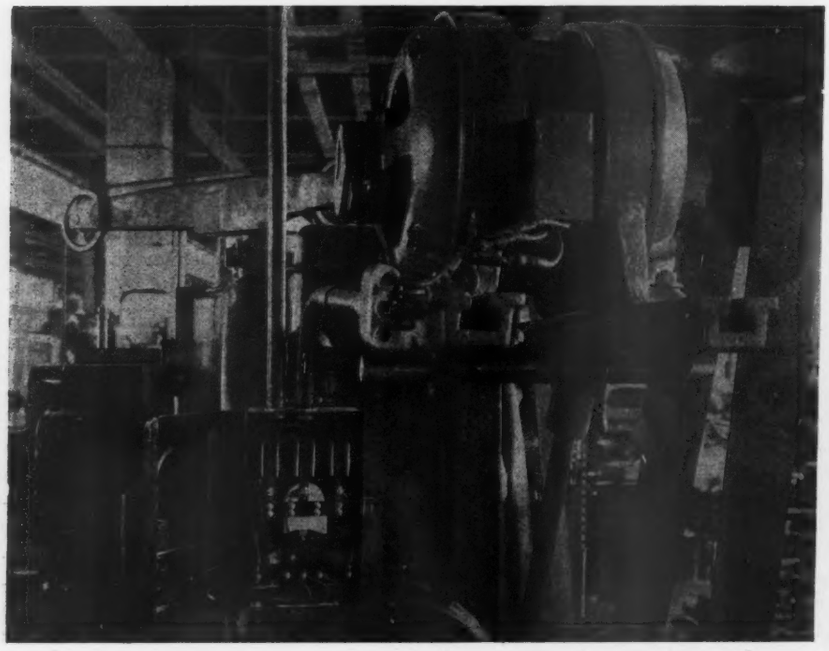
Manually-operated controllers for direct-current motors.

At the left is a Westinghouse drum controller in use on a shunt motor driving a conveyor belt. At the right is a Westinghouse faceplate starter controlling a d.c. compound motor on a lineshaft drive. Inasmuch as neither of these devices includes overload protection, this is provided for in both cases by Urelite (Cutter Co.) enclosed circuit breakers shown mounted above and below the controllers, respectively.

There are three common types of direct-current motors: namely, series, shunt, and compound wound, which differ from each other in the way that their fields are connected. The one requiring the simplest form of controller is the series motor. In this motor the armature and field are connected in series and all that is necessary for starting it, is to put resistance in series with the armature and series field. This is most commonly done by a faceplate starter, or drum controller in the manual type, and by a contactor panel in the automatic type. Some forms of drum controllers have segments revolving against fingers to make and break the circuit, while others have cam-operated contactors enclosed in a housing similar to the typical drum controller. The drum controller is commonly made for reversing service but does not provide overload or no-voltage protection to the motor. These must be provided for by means of a separate protective panel.

The faceplate starter is also used for series motors. In this type the segments are stationary and a revolving arm makes contact with them. This type of control must have separate protective equipment provided.

Automatic control for series mo-



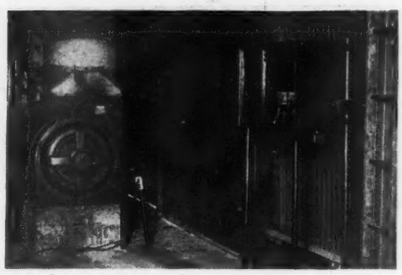
Across-the-line starter controlling a squirrel-cage motor driving a vertical turret lathe.

This Clark Controller Co. starter is operated from a push-button switch located at the front of the lathe, near the operator.

tors takes the form of panel-mounted magnetic contactors which connect and reverse the motor connections to the line as well as cut out steps of starting resistance. The closing of the resistance contactors is controlled by accelerating relays that are governed by the armature current or by time limit.

In selecting the controller for the series motor, it is mainly a question of whether manual or automatic control is required, which must be decided according to the advantages and limitations set forth at the beginning of this article. If the selection must be made from among the three manual types, it must be based mostly upon space requirements and individual preferences.

The shunt motor has its field shunted across the line so that the field is independent of the load current. This permits accurate speed control and it is on account of this characteristic that the shunt motor finds special application. The same types of controllers as described may be used with it except that provision must be made for adjusting the field strength if adjustable speed is desired. In many cases this takes the form of a separately-mounted field rheostat. In other cases the field rheostat can be combined in and operated by the drum controller itself. When an independent field rheostat is used it is necessary to provide a field-strengthening relay so as to prevent starting the motor on a weak field which would cause excessive sparking and probably a flash-over on the motor commutator. All shunt motors also require a field-failure relay, so that if the shunt field circuit opens, the motor will be disconnected from the line; otherwise it will overspeed and run away.



Combination of Rowan primary resistance starter and Urelite enclosed circuit breaker.

Here again the choice of the controller for a shunt motor simmers down to a choice between manual and automatic control. The manual type is mostly a matter of individual preference. In general, however, the faceplate type is used for non-reversing motors in the smaller capacities, while the drum type is used for reversing service and for the larger sizes.

The compound wound motor is a combination of the shunt and series motors. It is ordinarily used for constant-speed service and for constant-speed drives that require considerable starting torque. The control for it is similar to that of the shunt motor, except that provision is not ordinarily made for adjusting the field strength and hence a field-strengthening relay is not required. The same considerations govern the selection of the controller for this motor as were mentioned for the other types of direct-current motors.

Besides the controllers for direct-current motors that have been mentioned, there are many special types. In the main these are automatic types and are intended for special applications such as cranes and hoists, printing presses, machine tools, coal and ore dock equipment, rubber mill equipment, steel mill applications, paper manufacture, and the like. It is not within the province of this article to discuss such special types.

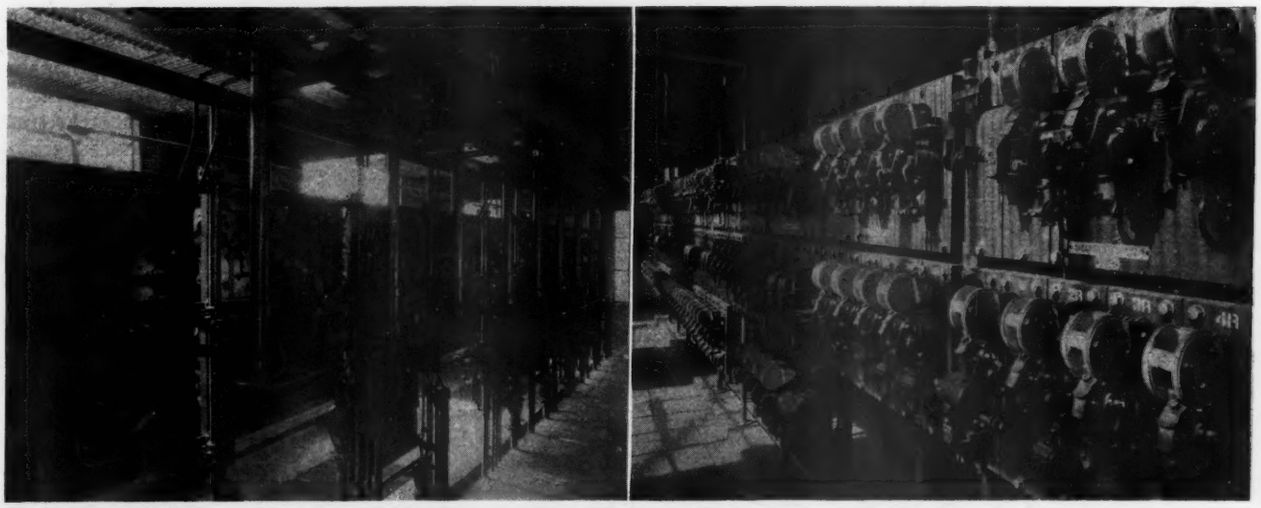
Protective devices have been mentioned throughout this article. A word or two more should be said, however. Besides the overload relays that have been discussed, circuit breakers and fuses are extensively used for overload protection. A very popular form of individual motor circuit breaker is the enclosed circuit breaker that is opened and closed by levers located on the case.

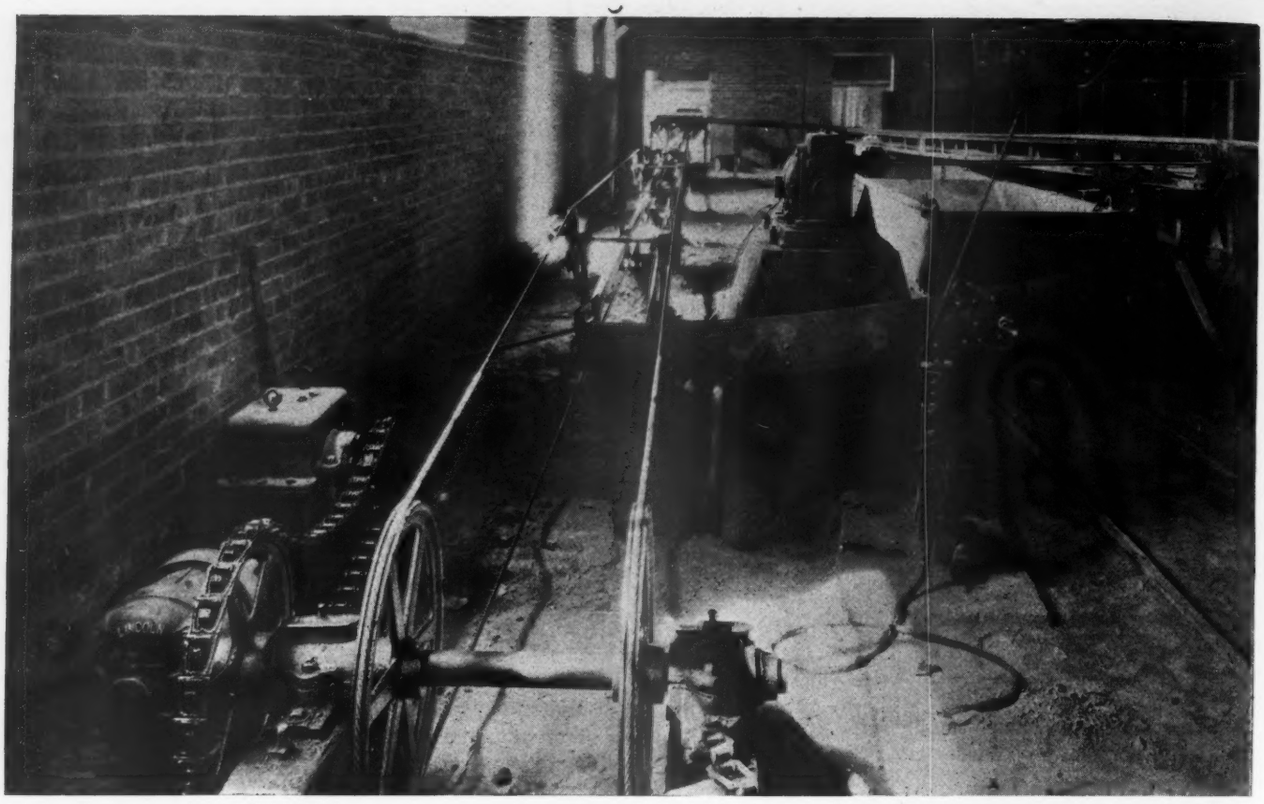
There is a temperature relay that may be attached directly to the motor and which, when the motor becomes excessively hot from overload or other reason, causes the motor to be disconnected from the load. We have already mentioned relays for protecting against no-voltage, field failure, and weak field. There are also relays for protection against over voltage, low voltage, phase reversal, single-phasing, overspeed and over-travel.

Such in brief is the field of controllers for general-purpose motors. The main thing to remember is that the controller is one of the most flexible elements in the power drive. It can be made to take care of many of the shortcomings of the drive provided consideration is given them at the time of selecting the control.

Here is an example of unusually good installation and housing of steel mill control.

This is part of an installation of 40 Cutler-Hammer inductive time-limit control panels. These panels are housed in a brick enclosure arranged on two floors, the upper floor being used for the resistors exclusively. Note in the left-hand illustration, the use of pot-heads on the conduits leading to the motors out in the mill.





This shows two worm gear speed reducers driving conveyors in a brick plant.

The reducer driving the cable conveyor at the left gives a speed reduction of 25:1 and is connected to a 1,740-r.p.m., 5-hp. motor. The worm reducer in the center of the illustration drives the conveyor at the right through a flexible coupling and long shaft. Horsburgh & Scott speed reducers are used here.

Examples of

Industrial Applications of Speed Reducers

together with a brief discussion of the various types of such units, how they are used, and the operating considerations involved in their selection

By FRANK E. GOODING
Associate Editor, Industrial Engineer

WHERE individual drives are used, it is often desirable to connect the motor as closely as possible to its load, particularly where it is not necessary to insert an elastic element in the drive to absorb vibration due to variable or shock loads. The development of the high-speed induction motor for industrial use introduced driving speeds which are much higher than the operating speeds of the driven shafts on practically all machines except some woodworking equipment and other high-speed tools. Manufacturers of machinery have not made a corresponding increase in the speed of their input or driven shafts. Where these machine drives had previously required some reduction, even with a slow-speed motor, considerably more reduction is now necessary. The effort to meet the demand for a compact unit, which would give the higher reduction ratios required, has resulted in the increased development and application of speed reducers or speed transformers, as they are frequently called.

In many cases, it had been the practice to use open gear trains or the open worm drive, often with cast or roughly cut teeth to obtain the necessary reduction. The higher speeds of the modern drive require better provision for lubrication and for keeping out dirt and dust, as well as more efficiently constructed and economically operated units for transforming the speed.

In general, four different types of speed reduction units, using gears as a reducing medium, have been developed. These are: (1) Worm gear reduction units. These consist of a driven worm or screw meshing in a worm wheel which it turns as rotation is imparted by the motor or other driving unit. (2) The compound or mill-type reducer, which is a series or train of plain or helical spur gears revolving on fixed centers and enclosed in a suitable housing. (3) The herringbone type, which is a modification of the spur-gear train, but uses double-helical or herringbone gears. (4) The spur-gear type with secondary gearing mounted at 120-deg. angles.

This fourth type of speed reduction equipment may be divided into three distinct groups and although the outward appearance is quite similar, each is different in its principle of operation, as is indicated by the accompanying sketch. These are: (*a*) The non-planetary type. This type of speed reduction unit employs a high-speed drive pinion meshing

with the three intermediate driven gears, which are journaled into the frame on fixed centers 120 deg. apart. These intermediate gears, in turn, mesh with and drive into a revolving internal ring gear, which is keyed through an integral web to the low-speed shaft. (*b*) The plain, spur gear type. This type of reduction is an adaption of the compound or mill-type (see 2 above) reducer. The secondary or intermediate gears are placed at 120-deg. angles to equalize separation strains on the drive pinion journal, and to distribute bearing strains on the secondary gear journals. (*c*) The planetary spur gear type. The planetary principle of speed reduction, as applied to speed reduction units, employs a high-speed drive or "sun" pinion, which meshes with and drives three intermediate or "planet" gears that are mounted at 120-deg. angles on the side of a free-running disk. These planet gears also mesh with a stationary internal ring gear which is integral with, or keyed to, the housing. when a rotative motion is applied to the sun or drive pinion, this motion is in turn transmitted to the planet or intermediate gears. The planet gears are journaled on a free running disk and, meshing as they do with the stationary ring gear, cause a rotation of the disk at a greatly reduced speed. The disk is keyed to the low-speed shaft (when used in a single-stage reducer) and transmits this reduced velocity to the low-speed shaft, and then to the driven machine or to a further reduction stage, when desired.

All of these various types of speed reducers are in common use and all are made with single and multiple stages of reduction. Each type has certain advantages, although all are widely used.

Where the ordinary gear train is used it is generally built into the machine. Where the bearings are not mounted substantially, or where the gear is mounted in the center of a long shaft with bearings at the ends, there may be sufficient spring in the shaft under heavy loads to cause excessive wear on the gear teeth. Gear trains should be enclosed so that they can be lubricated.

Worm gears of the single-reduction type give a right-angle, either horizontal or vertical, drive. This is of considerable importance in many cases for saving floor space, in that the motor can be placed alongside the machine instead of extending at right angles to the machine which it drives. This feature is noticeable in several of the illustrations in this article.

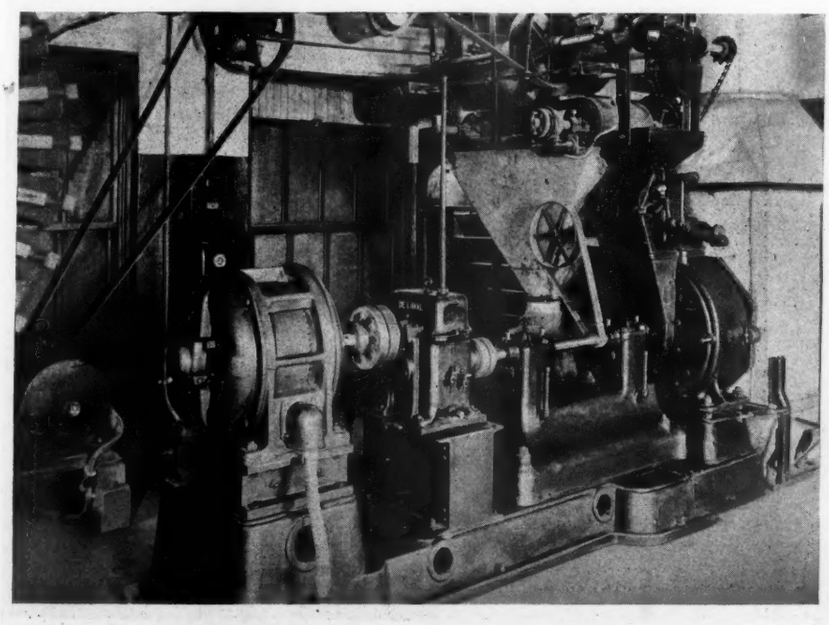
The present-day worm gear reducer must not be confused with the old type of worm which often consisted of a cast or roughly cut gear driven by a worm cut from ordinary steel. Worm gear reducers have been greatly improved within the past few years, until today many of them have anti-friction bearings, especially on the worm shaft, and improved methods of lubrication for both the gearing and the bearings. In practically all cases the worm operates in a bath of oil.

Improved cut worms of special alloy metals with modern bearings will operate at comparatively high speeds. The worm, naturally, has limitations on its efficiency in high reductions. Ordinarily, worm reducers are not made in standard units to deliver much above 100 to 125 hp. in the larger sizes under the best operating conditions of speed and reduction ratios. Enclosed spur gear reducers of the planetary, non-planetary and spur gear types are straight-line units; that is, the shaft of the reducer unit is attached to the end of the motor shaft through a flexible coupling and the two shafts are in a straight line. Where angle drives are necessary, the driving shaft of these types of speed reducers carries an enclosed bevel gear which drives the shaft of the reducer. This bevel gear gives a 90-deg. turn in the shaft.

In general reducers of all three gear types resemble a motor in appearance but are slightly larger or smaller, according to the type, than a motor of corresponding horsepower. The gears operate in an oil bath and some types are provided with anti-friction bearings.

Speed reducers are obtainable in standard units in a wide variety of reduction ratios. The manufacturer of these units makes standard shells or enclosing cases, each of which will take gears of fixed center distances. As it is possible to make gears with a larger number of ratios for each center distance, particular reduction ratios are obtainable by inserting various gears which will fit on these center distances. For this reason the ratios, as may be seen by consulting the manufacturers' catalogs, are in many instances, in decimal ratios. Thus, one manufacturer gives the ratio of a particular size of reducer as 10.285 : 1 or 9.643 : 1, instead of an even 10 : 1 ratio. However, many even ratios, and a 10 : 1 ratio in other sizes, are obtainable.

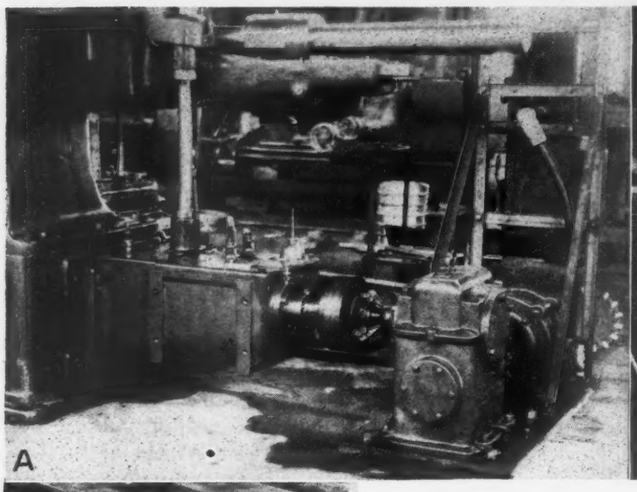
Different types of units have different standard maximum and minimum reduction ratios. However, manufacturers of the same type of equipment may supply units in different ratios so that the following statements on reduction ratios must be quite general. Examination of various manufacturers' catalogs indicates that standard reduction units are available in ratios approximately as follows: Herringbone reduction units: 1½ : 1 to 10 : 1, single reduction; 10 : 1 to 50 : 1, double reduction; and, 50 : 1 to 250 : 1, triple reduction.

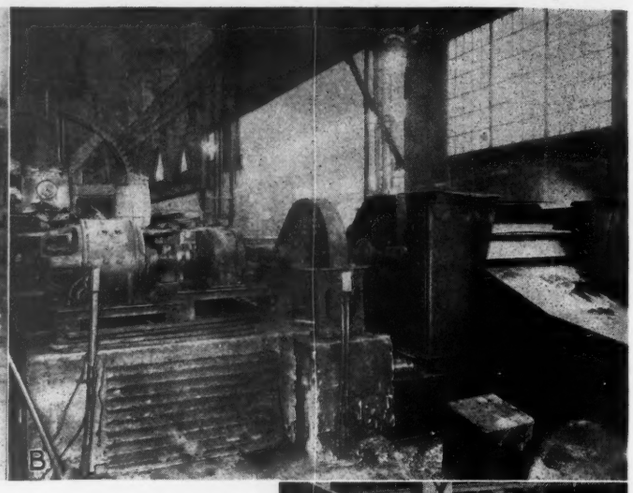


Speed is increased on this sugar pulverizer by connecting the motor to what would ordinarily be the low-speed shaft of this De Laval helical gear speed transformer.

Industrial Applications of Speed Reducers

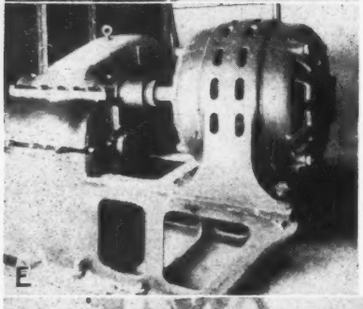
How Different Types of Equipment Are Used in Ten Plants


A


B

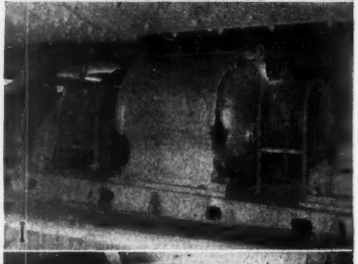
C

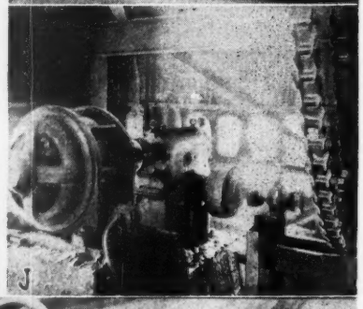
D

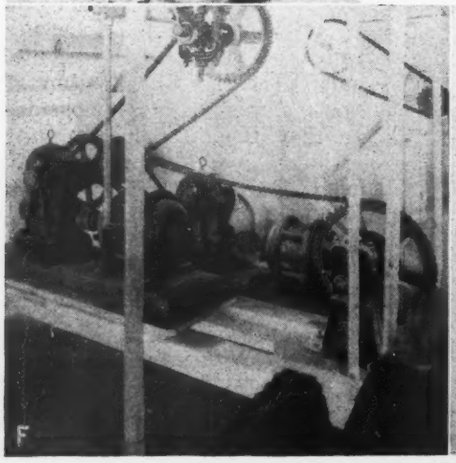

E

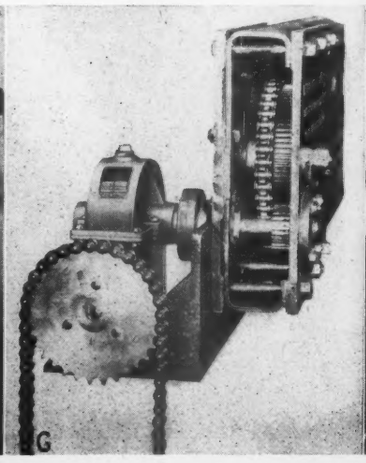
A—Boring mill driven by a Cleveland 5¼:1 worm gear from a 15-hp., 1,740-r.p.m. motor.
B—This James planetary reducer drives a conveyor through additional gear reduction.
C—Here a Winfield H. Smith worm gear reducer is used in combination with a chain for driving a conveyor belt.
D—A group of grinders individually driven through De Laval worm reduction gears.
E—Falk herringbone reduction gear and motor mounted for driving grain elevator head.
F—Combination of Foote worm gear reducers and roller chain drive connected to proofers and flour conveyors in a bakery.
G—This shows the method of connecting a Boston worm gear reducer through chains and an additional gear reduction.
H—In this case a Lewellen variable-speed transmission is connected in between the motor and the Foote worm reducer in the operation of a pan conveyor in a bakery.
I—This Jones gear reducer is direct connected through gearing to drive a cement kiln.
J—Here the worm on a De Laval reducer is placed above the worm gear. This 17½:1 reducer is connected to a 25-hp., 860-r.p.m. motor and drives a cement elevator.
K—A severe type of service for worm gear reducers is caused by an overhung drive, as in connection with this Horsburgh & Scott reducer belted to a mold-washing machine in a brick plant.

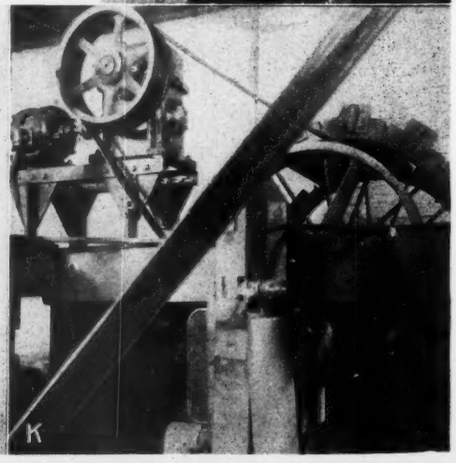
H


I


J


F


G


K

Worm reducers: 7:1 with maximum depending upon output and decreasing with increased rating. Double-reduction worm units give reductions of 100:1 and up. Planetary: 4:1 to 200:1. Plain spur gear type: 3:1 to 200:1. Non-planetary: 4:1 to 100:1 and up in multiple reduction. It should not be assumed, however, that all of these reduction ratios are available in all capacities. The maximum ratings vary somewhat with the reducers made by the different manufacturers, and to a larger extent than do the minimum ratios. Special units, of course, can be built for other reductions. The manufacturer should be consulted on any special reduction problem and it is advisable to give him all the information possible regarding any particular installation, especially as to the service conditions, the horsepower to be delivered, the input and output speeds, and the type and horsepower of the drive and the machine driven.

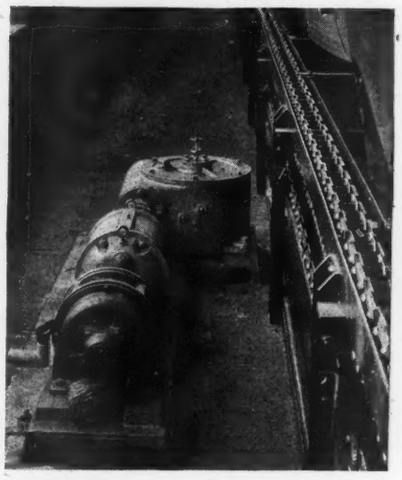
Worm Gear Speed Reducers Used for High Reductions

Higher reductions are usually obtained by combinations of worm and gear reducers, and there is practically no limit to the reductions obtainable in this way. Reductions up to 50,000:1 can be obtained through standard gear units, according to one manufacturer, and probably higher reductions could be obtained through the use of a double-reduction worm gear.

Herringbone reduction units alone are built for heavy power transmission. These units are made in capacities of several thousand horsepower. Other types of gear reducers ordinarily are seldom made much above 100 hp., although some units are made as standard equipment up to 250 hp. There is considerable controversy among industrial operating men regarding the relative merits of herringbone units and other gear reduction units within the field of both, from 50 to 75 hp. and up. Herringbone and helical gear reduction units are totally enclosed and the gears operate in an oil bath.

Extent of Industrial Applications of Speed Reducers

Speed reducers are used in practically every line of work where it is desired to reduce the speed from the driving unit to the driven unit in a fixed ratio. Probably the greatest demand for these units exists in the cement industry where a large portion of the machines are operated at comparatively low speeds. Here the dust is such an important factor that practically any type of open metallic drive would be worn out very quickly. As all of these modern types of reducers are totally enclosed, the dust does not affect them. Also, under dusty surroundings reducers are frequently subject to neglect, but as practically all makes carry special provisions for lubrication, particularly on the gears, they require only infrequent attention.



These Jones spur gear and horizontal worm gear reducers drive a conveyor on the ceiling of the floor below.

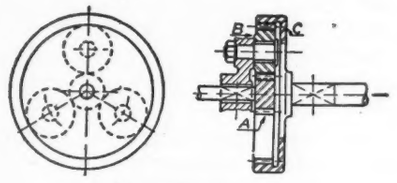
Other important fields for speed reducers are in rubber plants, for the operation of the rolls, calenders and much of the other low-speed equipment. In chemical works, speed reducers are used in the operation of agitators, mixers, conveyors, grinding and rolling mills, and other equipment. Textile mills, coal mines, ceramic and brick plants, and steam power plants for operating auxiliary apparatus such as coal crushers, conveyors, stokers, and so on, also offer important fields for the use of speed reducers.

Nearly All Conveyors Require Speed Reducers

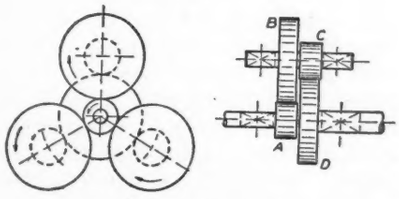
In addition, a large number of other industries use reducers to a certain extent. For example, practically every industry has use for conveyors which, if operated at very low speeds, frequently use a speed reducer of either the worm or gear type, or a combination of these. The assembly conveyor lines in automobile plants, for example, are generally driven by a motor through a gear speed reducer, a worm reducer and a variable-speed transmission. This not only gives the low-speed travel of the conveyor chain but also permits varying the speed to take care of increases or decreases in production demands.

An interesting application of a worm speed reducer is shown in the illustration at the beginning of this article. This is a Horsburgh & Scott series 1400, Type WB worm gear speed reducer driving a cable conveyor for loading brick pallets. This conveyor is driven by a 1,740-r.p.m., 5-hp. motor and the speed reduction is 25:1. The small floor space necessary and the generally compact arrangement are well shown in this illustration. Additional reduction is given to the cable conveyor through a link chain. Another worm speed reducer is shown in the center of this same picture. On this drive it was necessary to mount the reducer on a cement pedestal a considerable distance from the conveyor (at the right) which it drives through the single flexible coupling and shaft extending entirely across the track.

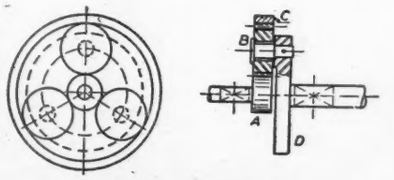
An interesting installation of a straight-line drive spur gear reducer is shown at the bottom of page 480.



A—Non-Planetary Type



B—Spur Gear Type



C—Planetary Type

This shows the arrangement of gears in each of the three types of gear reducers.

In all types the gears are enclosed in a circular case and mounted 120 deg. apart. The relation of the gears and their operation are different in each type. These types are: *A*, non-planetary type, *B*, plain spur gear type and *C*, planetary type. Each type is described in detail in the accompanying text.

This is a Type 4CA, 15:1 ratio, Albaugh-Dover, spur gear speed reducer operating at an input speed of 1,200 r.p.m. from a 40-hp. motor. In the illustration, the motor (at the right) is shown covered by a sheet-metal helmet to protect it against moisture. This reducer is driving a 16-in. spiral conveyor 70 ft. long in a mill producing special ground feeds. The conveyor is fed by 13 presses and operates continuously the year around. Should any units in the drive fail for even a short period of time it would mean the stoppage of the entire plant. This unit is equipped with alloy steel gears mounted on 10 heavy-duty self-lubricating roller bearings.

Where it is desired to employ an angular drive, angular gear reducers are used, as shown on the top of page 481. This is a Ganschow planetary reducer unit driving conveyor heads in a cement mill. In this case a straight-line drive would have extended the motor into the aisle and the angular drive saved considerable floor space. The angle may be changed so that the reduction drive is vertical and either up or down.

Speed Reducers Can Be Used for Stepping Up Speed

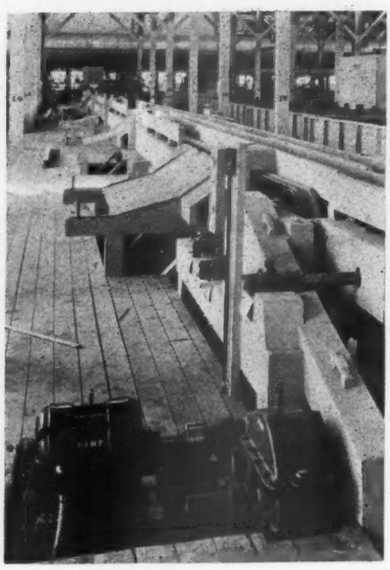
In some cases reversed connections are made to the speed reducer and it is used for stepping-up speeds. An example of that is shown in connection with the sugar pulverizer illustrated on page 477. This is a De Laval single-stage helical gear reducer connected in with flexible couplings on each side of the speed transformer.

Considerable care must always be exercised in using speed transformers for stepping up speed to see that the ratio is not too high, because the operation of stepping up speed with a transformer is very much like trying to lift a weight with the short end of a lever. Also, obviously, as the reduction increases the torque would necessarily decrease. This is the reverse of the condition when stepping down speeds in that the torque increases as the speed decreases.

An interesting combination of speed reducer units is shown in the illustration on page 479 of the Jones reducers in an automobile plant. This shows a Jones No. 12, double-type, style 1 spur gear speed reducer with a 56:1 ratio connected to a Jones No. 14 horizontal worm gear speed reducer with a 35:1 reduction ratio driving a conveyor on the floor below. This unit is driven by an 1,800-r.p.m., 1-hp., induction motor.

The left-hand illustration below shows the use of a Foote non-planetary speed reducer which drives a rack on a transfer table for loading and unloading or pulling annealing furnaces. The single transfer table serves both furnaces.

A number of other installations are shown in other illustrations in this article and in the special page of photographs on page 478. A description of each accompanies the illustration.



The Falk herringbone speed reducer in the foreground drives the conveyor on an automatic sorter in a large lumber mill.

Operating Conditions to Consider When Using Speed Reducers

It is always advisable to use a flexible coupling in connecting the motor to the speed reducer, because of the difficulty in maintaining perfect alignment. Also, the unit should be mounted on a substantial foundation.

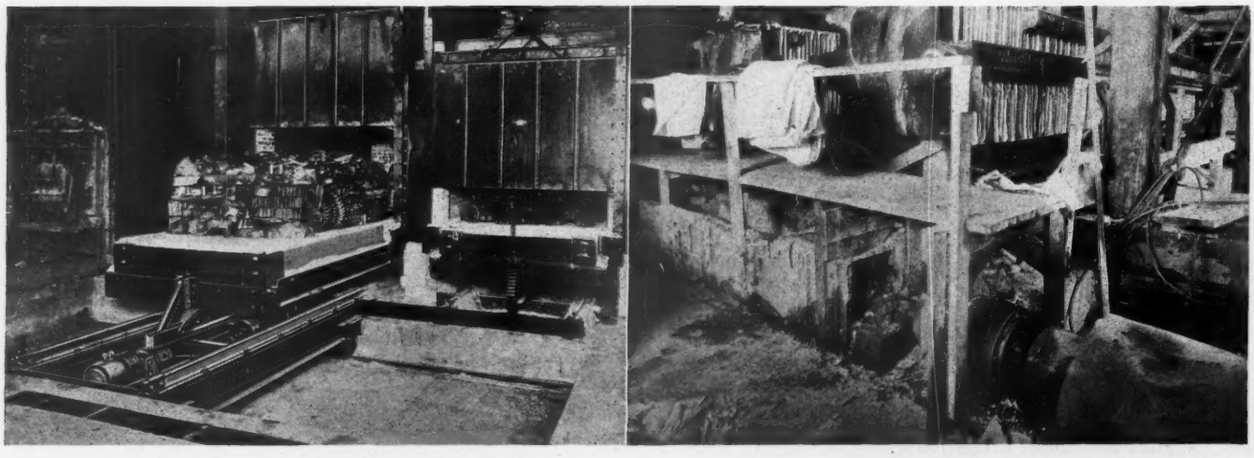
Practically all manufacturers of reducer units will supply cast-iron foundation plates or bases on which the motor and its reducer may be mounted. It is advisable to mount this base on a substantial concrete foundation.

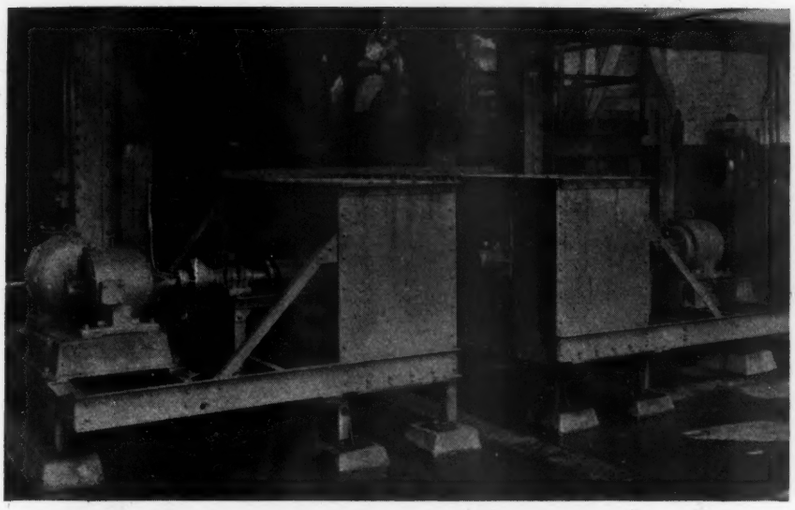
One point which is frequently overlooked by users is that in selecting a speed reducer for any particular service, careful consideration should be given to the power output of the reducer or, in other words, to the power required to drive the machine.

However, many users consider it necessary merely to specify the reducer unit from the standpoint of the horsepower and speed of the motor drive and reduction ratio only.

A Foote non-planetary gear speed reducer helps to fill and pull these annealing ovens by driving a rack in the transfer table.

Here a spiral conveyor, 70 ft. long, is driven by a 1,200-r.p.m., 40-hp. motor through a 15:1 ratio Albaugh-Dover spur gear speed reducer.





Although gear reducers are usually straight-line transmissions, this Ganschow planetary reducer connected to conveyor heads is a right-angle drive. This change in direction is obtained by means of bevel gears in the reducer.

Also, users should remember that the type of service and the operating conditions have a great deal to do with determining the proper size of drive, the same as with any other mechanical unit employed in power transmission. Severe operating conditions necessitate giving special attention to the use of service factors in selecting a unit of the proper rating.

It would be well worth while for users to take advantage of the opportunities of consulting with the manufacturers of the reduction units regarding an installation, rather than try to order from the catalog.

Quality of manufacture is also a very important point in speed transformers. This becomes more important with the severe service conditions and increased power and speed that are the order of the day. For that matter, quality is a point to be given very careful consideration in connection with any equipment.

EDITOR'S NOTE: Acknowledgment is made to the following companies for information and photographs used in this article: Albaugh-Dover Mfg. Co., Chicago. Ill.; Boston Gear Works Sales Co., Norfolk Downs, Mass.; Cleveland Worm & Gear Co., Cleveland, Ohio; De Laval Steam Turbine Co., Trenton, N. J.; Falk Corp., Milwaukee, Wis.; Fawcus Machine Co., Pittsburgh, Pa.; Foote Bros. Gear & Machine Co., Chicago, Ill.; Wm. Ganschow Co., Chicago, Ill.; Horsburgh & Scott Co., Cleveland, Ohio; D. O. James Mfg. Co., Chicago, Ill.; W. A. Jones Foundry & Machine Co., Chicago, Ill.; R. D. Nuttall Co., Pittsburgh, Pa.; Winfield H. Smith Co., Springville, N. Y.

Reducing Friction Losses

(Continued from page 463)

or roller chains, and on some silent chains. As a matter of safety to the workmen, as well as protection to the chain, it is always well to have chain drives enclosed. More detailed information on the selection, application, and lubrication of chain drives will be found in articles which appeared in the July and September, 1923, and the March, 1925, issues of INDUSTRIAL ENGINEER, and on page 456 of this issue.

There has been a general tendency during the past few years to use higher lineshaft speeds. For one thing, this permits the use of high-speed motors, which are more efficient and less costly than low-speed motors. Operating lineshafts at higher speeds than were formerly used does not require so great a reduction in speed between the motor and the lineshaft. Consequently, better pulley ratios can be employed. In some recent installations in which high lineshaft speed is either desirable, or at least not objectionable, short lineshafts have been coupled directly to the driving motor, which turns at 1,200 or 900 r.p.m. This method of driving a shaft makes it possible to eliminate at least one belt and reduces correspondingly the friction on both motor and lineshaft bearings.

In some other installations in which it was not feasible to drive the lineshaft at the speed of the motor, a speed reducer has been used between the motor and the lineshaft. In this way the advantages of a direct drive are obtained.

Precautions to Be Followed in Welding Cans, Barrels or Tanks

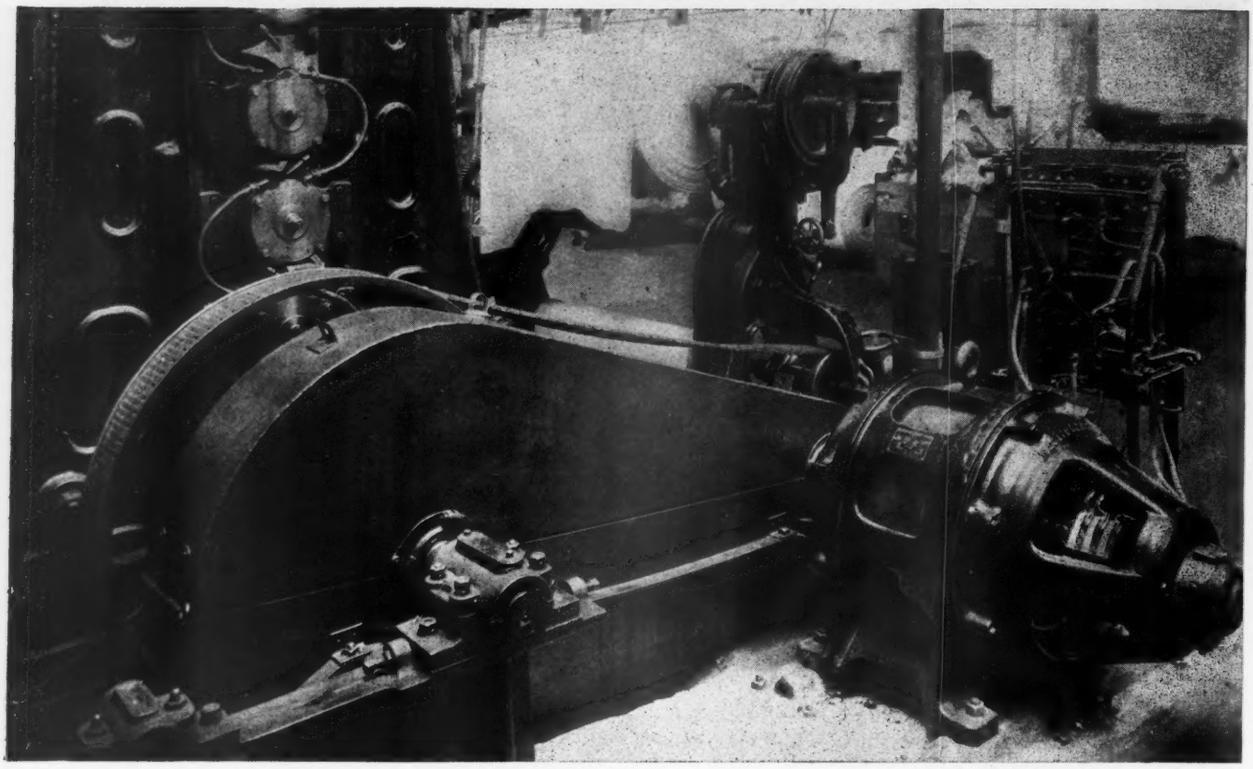
REPAIRING, adding fittings or altering metal tanks, barrels, or drums, requires the taking of special safety precautions. A large proportion of these containers have been used to hold oil or other liquids which, under the action of the welding heat, may catch fire, or even explode.

Two precautions should always be taken in all cases, according to recommendations of The Linde Air Products Co., New York City: The container should be thoroughly cleaned and also vented to prevent the accumulation of gases under pressure due to the heat of the welding. It is well to make it a rule to clean every container before welding, regardless of what the operator *thinks* that it may have formerly contained.

Live steam will effectively remove traces of oils or liquids, such as gasoline and so on; scrubbing with a lye solution will take out oily materials. There are also a number of special cleaning preparations which may be used. One of the easiest and safest ways of protecting the operator is to flush the container thoroughly with water, then to turn it so that the damaged section is uppermost, and fill it with water nearly up to the defect. The unfilled section of the container should be vented, however. The welding can then be carried on with the least possible open space inside.

This precaution applies not only to welding, but to other repairs. Even a blow from a hammer may strike a spark or friction may generate enough static electricity to cause an explosion if inflammable vapor is present.

Handhole or other fittings should always be opened before beginning the cutting or welding operation, as these openings provide means for the release of heated air. It is safest to take every possible precaution to prevent air or gas pressure from building up inside tanks or barrels when the flame is applied to the metal. It is not safe to take the chance that no liquid which may cause gaseous vapor has got into containers unsuspectedly. It takes time to fill a tank with water, but not nearly so much time as some men in a hurry have spent in a hospital.



When bearing pressures are high, a reliable and efficient method of lubrication must be used.

In this paper mill installation, use is made of a forced-circulation lubricating system, in which the oil is circulated through the bearings, cooled, filtered, and returned to the bearings. In this instance the chain drive between the motor and the machine is enclosed and operates in a bath of oil. The chain is thus protected and thorough lubrication assured.

Progress made in

Lubricating Power Drives in Industrial Plants

through the development of better lubricants and improved methods of application that have been necessary to meet changed operating conditions

ONE of the most outstanding features indicated in the combined progress of lubrication and mechanical developments during the past few years is the demand in many classes of industry for higher speeds. Highly-developed competition, characteristic of modern industry, is responsible for the necessity for greater production with a minimum of increase in operating expense. Without increasing the cost of equipment or the overhead expense involved in larger equipment, the speeding up of machinery constitutes one means of increasing production.

This tendency is evidenced not only by the improved design of new machinery being built and installed, but also by the rehabilitation and improvement of old machinery to meet the requirements of modern industry. Equipment that was built for the conditions of a more leisurely production period is constantly being operated at approximately the speed of newer types of similar equipment.

This change has been met both by a recognition on the part of the designers of equipment and by increased attention to the improvement of conditions on machinery already in service. Speeding up of equipment depends primarily upon the efficiency of lubrication of the bearings, gears and other parts of the machine, because it is upon the proper functioning of these that the strain of extra production falls.

A machine, for example a paper machine, may operate at a speed of 800 f.p.m., for which speed the bearings and other parts have been correctly designed. Conditions may demand that the paper machine produce at the rate of 1,000 ft. of paper per minute, or even more. This would require the introduction of an additional factor of safety to make up for the burden of the overload imposed by the higher speed.

Parts of machines first affected by any increase in speed are naturally the bearings, gears and other frictional surfaces. These must move at a more rapid rate and more heat will be generated by the higher rate of motion. Therefore, some means must be introduced to provide better lubrication, a more efficient lubricant, and to insure its application regularly and positively, in order to offset the increased speed. These changed conditions demand alterations in design, or in the details of design, so that the proper lubricant may be used in an efficient manner.

The interest and attention of scientists and engineers has been directed to the behavior of oil and oil films under various conditions.

EDITOR'S NOTE: The information on which this article was based was furnished by the Technical Department of the Vacuum Oil Co., New York, N. Y.

Recent papers and books upon the subject show the keen appreciation of the value of, and the necessity for, mechanical conditions that will promote the efficient use of lubricating oils. Widely theoretical as some of these have been they, nevertheless, have exerted an influence upon the practical application of oil.

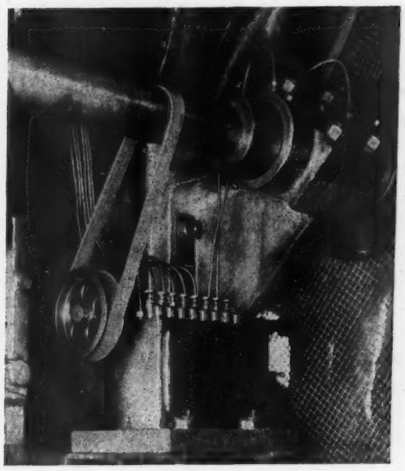
In the early days of machine design and operation, little thought was given to caring for the needs of the moving parts. It was recognized that some form of medium must be introduced between the frictional surfaces so that the parts could move one on another. The crude designs and slow speeds of operation did not make very serious demands upon the lubricant, and grease or tallow was commonly used.

Grease, although it performed its function in the older, cruder types of machine, did not perform its function with the efficiency of a fluid lubricant. Although metal-to-metal contact was avoided to a certain extent, the factor of efficiency of the lubricant itself had still to be considered, particularly as speeds were increased. Power consumption became a factor, as well as facility of oil application and freedom from wear.

It became apparent to engineers studying lubrication that fluid friction in an oil, especially in the lighter oils for bearing service, was considerably less than that of grease. Lubrication failures, due to the use of grease and unsuitable oils inefficiently applied, often made it impossible to keep the machines up to their normal speeds. Improvements in operation were obtained by better lubrication methods and by the employment of the most suitable oils. This improvement was evidenced both in terms of lower power consumption and reduced wear. Thus oils superseded greases as lubricants, bringing in their wake, changes in the design of bearings and lubricating appliances.

There has been a stepping up all along the line in matters pertaining to lubrication. Hand-oiled bearings are rapidly giving way to drop-feed cups, wick-feed cups and other semi-automatic appliances. Also, bearings formerly equipped with such cups and semi-automatic lubricating devices are being equipped with splash or circulation systems.

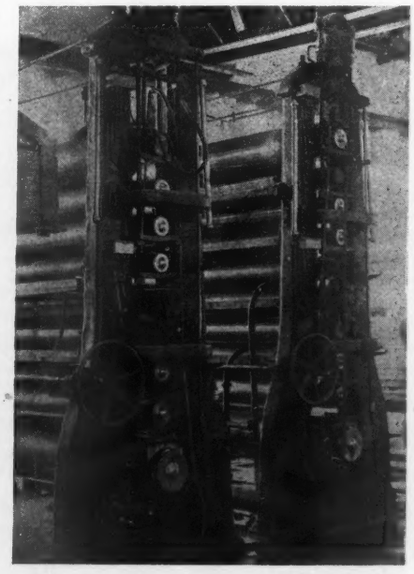
These advances in methods of application have been accompanied by a corresponding advance in the manufacture of lubricating oils. Even oils for lineshafting cannot be used broadly if the best results are to be obtained. The distinction in oils due to body, general characteristics, and methods of refining, make one oil more suitable for certain purposes than other oils.



The bearings of this punch press are lubricated by a mechanical force-feed lubricator.

Inasmuch as there is little wastage, high-grade oils may be used economically by the use of devices of this character, which feed the lubricant positively.

The theory of "floating" a shaft on an oil film, while not new, is basically the idea of the whole modern practice of lubrication. The trend of developments during the past few years has been to emphasize the need for oils that will cover each specific condition of frictional contact and provide that oil film in the most economical manner. Lubrication has become, instead of being an isolated factor in the maintenance and operation of a plant or mill, a factor affecting every branch of industry in terms of production. There has been a recognition on the part of manufacturers and designers of machinery that no machine can run efficiently or effectively and maintain its proper operating condition without due provision for the use and application of the proper lubricant.



This shows an application of the wick-feed principle to the bearings of a calender stack in a paper mill.

This general increase in the knowledge of the principles of correct lubrication, due to the publication of treatises by lubrication experts, engineers, and scientific writers, has been of invaluable assistance in the improvement of lubrication practices. The theory of lubrication is taught in colleges and universities of standing, where, only a few years ago, little or nothing was known of the subject. Today the technical graduate leaves school with at least a working knowledge of the basic principles of lubrication.

Lubrication practice has improved immeasurably. The idea that lubricating oils, no matter how high grade the product, are far cheaper than repair parts, renewals, and power costs, has taken root extensively, with the result that there is a demand on the part of the consumers for high-grade products, where only a few years ago it was impossible to interest the users of the same class of equipment in anything but the cheapest grade of oil. A number of "low-grade oil" users have come over into the class of "high-grade oil" users within the past two or three years, and others are on the way.

The human element, which formerly predominated in matters of lubrication, is gradually being eliminated. The uncertainty and the lack of care, the periodic application such as was inherent with hand-oiling methods, and the existence of isolated points of application, are today being supplanted in many important classes of machines by automatic devices which deliver the oil continuously and in positive, controlled quantities, thus providing constant and controlled application.

These systems gave rise to a new set of oils to meet the requirements of the new conditions and of new methods of treating the oil while in service. The circulation system, which was necessary to the operation of the steam turbine at high speeds, is fast finding favor in other indus-

tries, not only for bearings but for gears. Machine tools, paper machines, steel mill machinery, reduction gear sets, and so on, may be listed among the groups that have been converted to the use of circulating systems for lubrication. Splash lubrication has come into general use on several classes of machinery to which it is adapted. This has also created a demand for superior grades of oil.

Other modern systems of lubrication are advancing the cause of economical lubrication. Mechanical force feed lubrication forms a positive means of introducing high-grade lubricants in an economical way, as is necessary with the use of high-grade oils. The cost of the lubricator, which was a stumbling block to many users of machinery, has proven to be a small investment compared to the benefits derived from improved lubrication and the economical use of high-grade lubricants.

The modern tendency is to use automatic lubricating systems wherever possible and to demand the use of the highest grade lubricants obtainable in such systems.

The most pronounced advance in the science of lubrication has been the recognition on the part of manufacturers and users of mechanical equipment, of the fact that any improvement in the means of applying lubricants, or in the efficient distribution of the oil in the bearing or cylinder or between the gear teeth, or the more careful selection of the oil to insure the use of the most suitable lubricant for the conditions, will improve the running of the machine, prolong its period of usefulness, and ultimately result in economy. This is indeed no small step in assuring to the science of lubrication its proper place in the industrial world.

The actual performance of correct lubricants, when properly applied, and the tangible results obtained thereby have been instrumental in bringing about the change in attitude toward the lubrication problem. A few cases where the performance of lubricants has been recorded will serve to show the importance of improved lubrication and will demonstrate that a great economic gain is possible by the study and application of scientific methods to every phase of machine operation.

One of the economies of modern lubrication is obtained by long service of the lubricant. In systems where the oil is used over and over, it is important that the oil be of such a nature that it will withstand the high temperatures, continuous use, contamination from outside sources, and deterioration due to chemical action.

Circulation and splash systems, both of which use oil in quantities, cannot prove to be an economy, as far as oil consumption is concerned, unless oils that will give long service are used. Although there are many applications of these systems of lubrication, the steam turbine offers an excellent example of severe, continuous service. Many cases have been noted where excellent service has been rendered in such systems, as, for example, in the case of a 3,200-kw. steam turbine which ran for two years on a single charge of oil. This turbine was practically in continuous operation during the entire period. During that period 40 gal. of "make-up" oil were used or an average of 20 gal. per year. Subsequent to the removal of the oil from the system, its condition was considered to be sufficiently good to warrant its use about the plant for other less important lubrication work.

In any unit where a quantity of oil is required for each charge of oil, the probable length of the life of the lubricant must be carefully considered. Also, in small splash or circulating systems long life is a factor both from the standpoint of the cost of the oil, as well as from the cost of the labor involved in draining, cleaning and replacing the oil.

Oil consumption is another item of lubrication that is capable of reduction. In one case, by way of illustration, a band saw employed for cutting cork was using oil at the rate of 1 gal. a day, which apparently was not too much. However, the use of the right oil applied at a rate of feed that was sufficient to supply the requirements of the machine, reduced the oil consumption to 2 qt. per day, thus effecting a saving of 50 per cent of the original amount. Such savings effected on the machines throughout a whole plant have been made with the controlled application of oils of high lubricating value. When considered on a yearly basis in terms of dollars and cents, this saving considerably reduces the operating cost of the plant.

Another saving along the same line is to be found in the case of a group of 15, 1-ton electric mine locomotives. Each of these units was using 1 qt. of oil every five days. This was reduced to 1 pt. of oil each per five-day period.

The fact that these economies in the cost of the lubricant and other economies in the form of reduced repair costs can be made at the same time, deserves careful attention. A reduction in oil consumption, accompanied by increased cost of repairs and renewals of parts would be poor business. However, the reduction of oil consumption while mechanical

Here is a successful application of a wick-feed box with multiple feed to the bearings of a wood working machine.

The rate of feed of the lubricant is controlled in this case by varying the amount of wicking in the top of each feed pipe. With these boxes it is possible to stop the feed to all bearings by throwing a single lever.

conditions are maintained or improved, is to be desired at all times.

In one plant making a well-known product, the mill foreman estimates that there has been a reduction of 50 per cent in the number of bearing renewals during the 6-mo. period subsequent to the installation of improved lubrication. Simultaneously, there was a reduction in the cost of lubricants from $1,700 to $1,350 and a further reduction in the cost of labor for applying them. The savings given in this last example do not take into consideration the increased production due to the operation of the machines without shutdowns for repairs.

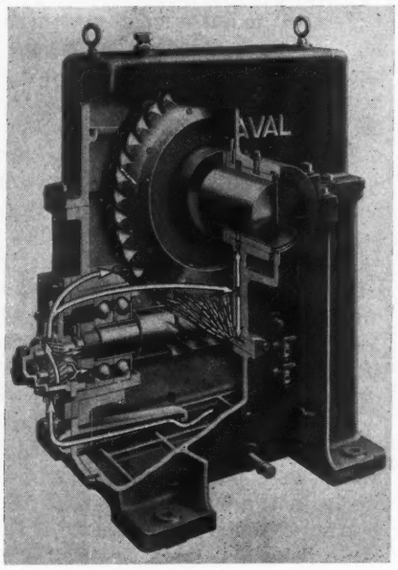
Another instance of a similar nature occurred in a woodworking plant operating eight stickers. Here an average of one sticker bearing had to be replaced every week at a cost of $15. Subsequent to an analysis of the conditions and the application of suitable oil, it was found that it was necessary to replace a bearing only every 3 mo. which effected an annual saving of $690. The superintendent is authority for the statement that hot bearings are unknown in his plant now.

Such figures taken from actual experiences in the industrial world must be accepted as the most convincing evidence of the efficacy of lubrication when applied according to the best practice. That proper industrial lubrication is a "tremendous trifle" is obvious from a consideration of the previous instances.

Power consumption, while not a salient factor in the operation of every machine, represents an item of expense to the plant or factory whether the power is generated in the plant from fuel of one kind or another, or whether it is power purchased in the form of steam or electricity.

Two causes of excessive power consumption are inadequate lubrication or the lack of effective lubrication. The first of these results from the failure or inability of the oil to supply and maintain a complete oil film. This results in friction of the metal surfaces, which in turn causes wear of the surfaces, as well as increased power consumption. Therefore, any improvement in the lubrication from the standpoint of reduction of wear is likely to result in a reduced power consumption.

The other cause of excessive power consumption is the result of using an oil which, although it may protect the surfaces from wear, is too heavy from the standpoint of "oil drag." Considerable power may be consumed in the work of overcoming friction in the oil itself. Correct lubrication provides for the prevention of metal-to-metal contact, and at the same time insures the least friction loss which would result from the use of an oil heavier than necessary. For example, in a paper mill a reduction in the cost of lubricating oils was accompanied by a reduction of 16⅔ per cent in power cost, in spite of an increase in production in the plant during the same period.



One type of positive pressure oiling system for a worm gear speed reducer.

The splash system, wherein the worm dips into the lubricant and the oil thrown off from the gear is allowed to find its way down the sides of the case to the bearings, is generally used on speed reducers of this type that are designed for ordinary operating conditions. However, in the case of large-capacity units, or where the speed is high, the splash system may not be satisfactory. The illustration shows the method used in the De Laval worm reduction gear to supply the bearings with oil under pressure. As will be seen, the oil is drawn through a strainer located some distance above the bottom of the oil reservoir, by a pump which delivers it through passages in the casing to spray nozzles located on both sides of the worm, and also to all bearings.

Direct power savings are most noticeable in the case of prime movers, such as steam engines. In the lubrication of cylinders, the piston sealing effect of the oil is to be obtained in addition to the factors affecting power economy just mentioned. A change of lubricating oil in one plant reduced the fuel oil consumption for power generation from 2,100 gal. per day to 1,700 gal. per day, thus showing that the theory of correct lubrication works out in practice in no unmistakable terms. The chief engineer of the mill in question confirms these figures.

Labor is a big item of expense in the operation of most industrial plants. Any saving in this respect is a clear profit. That lubrication, in the modern sense of the word, and lubricating devices which are designed to reduce the care and attention necessary with hand-oiled machinery have contributed to the reduction in the expense of plant and mill operation, is amply demonstrated by actual figures.

Savings in the cost of the application of oil to bearings are shown in the following example. A tool manufacturer applied inexpensive automatic devices to the overhead shaft bearings and found that one filling of these devices would last three weeks. However, the devices are filled every two weeks at a total cost for the year of about $37. Previously, the bearings were oiled by hand daily. This operation required 3 hr., at a cost of approximately $1.50 per day or a total cost of $9 per week. Calculating this on a yearly basis shows that it cost $450 to hand-oil the same bearings that are now being lubricated regularly and continuously at a cost of approximately $37 over the same period.

The application of the lubricant is not the only labor expense involved. Other labor savings, directly traceable to the scientific application of oil, are evident in other phases of plant operation. The following is an example of a saving in labor attributable to better lubrication, which resulted from the elimination of the necessity for cleaning compressor valves. The excellent condition of the valves is a direct result of the right use of a suitable lubricant. In the plant referred to, the valves in the cylinders of three gas compressors had to be cleaned monthly, representing an expense for labor of about $40 per cylinder. During the first 6 mo. after a better lubricant was adopted, the valves were cleaned only once, thereby effecting a saving of approximately $200 per cylinder, or $1,200 for the whole plant. The slight amount of deposit found on the valves at the end of six months was easily removed with kerosene, whereas with the oil previously in service, the hard carbon deposits caused considerable breakage of valves.

In another plant, a paper mill, the work of six men was required for one

day each week to clean the oil from floors and machines, due to the over-application of oil. With improved lubrication, six men spend one day every fourth week cleaning up oil. This represents a payroll saving of 18 man-days per month which amounts (in this particular mill) to $72 per month.

Labor savings may also be traced to other places in the plant or mill as a result of the care and attention to the selection of the right oils and their application by modern methods.

These instances of the bettered conditions that have resulted from improved lubrication amply bear out the statements made in the earlier part of this article. They offer a concrete reason why so much interest and enthusiasm have been aroused during the past few years in the study of lubrication problems and the development of lubricating oils of the right characteristics to meet the conditions of service encountered today.

When the user of oil is assured of long service of the oil he puts in his system, that is, economy by reason of the better lubricating value of the oil; when he is assured of reduced repair costs in terms of dollars and cents — something that actually shows on his books and about which there is no guesswork or theorizing; when he sees his cost of power consumption decrease or his bill for fuel reduced appreciably; when he finds that some of the men whom he had employed about the plant for the application of oil, or for cleaning his machinery or his floors about the machines, may be released to perform some really productive work about the plant, he is then convinced that modern lubrication is an accomplishment of real importance to the whole industrial field.

Care of Leather Belt Drives

(*Continued from page 468*)

leather belting that requires no more than one take-up and often runs 6 mo. or a year without moving the motor back more than 1 in. on the sliderails.

Methods of lubricating and dressing belting leather have also been greatly improved by the manufacturer, so that the best belts today last longer and have a higher leather fiber content. Every man who has anything to do with the maintenance of leather belts should have a set of simple rules on the care of leather belting in the shop. These are very interesting and are available in booklet form from the manufacturers of leather belting, for anyone who will ask for them.

The belt is but a small part of the cost of each production machine, but, like the arteries in the body, it is very important. A good leather belt, bought according to standard tests, will increase production and save trouble and money for the company. A leather belt should always be purchased on quality, because the quality leather belts are always the least expensive, so much so that no other kind should even be considered. The testimony of every practical shop man will bear out this contention.

In summarizing, some of the simple rules which should be followed by all power transmission men are given in the box on page 466. Operating executives who see to it that their belts are given the proper attention, will not only have a better operating plant, but will have a new and higher respect for reliable leather belting.

Recommended Method of Splicing Wire Rope

IN ORDER to prevent appreciable loss of strength at the splice in a wire rope, it is customary to make the length of the splice not less than is given in the accompanying table for ropes of different sizes.

Diameter of Rope	Length of Splice
¼ in.	15 ft.
⅜ in.	20 ft.
½ in.	24 ft.
⅝ in.	28 ft.
1 in.	32 ft.
1¼ in.	36 ft.
1½ in.	40 ft.
1¾ in.	45 ft.

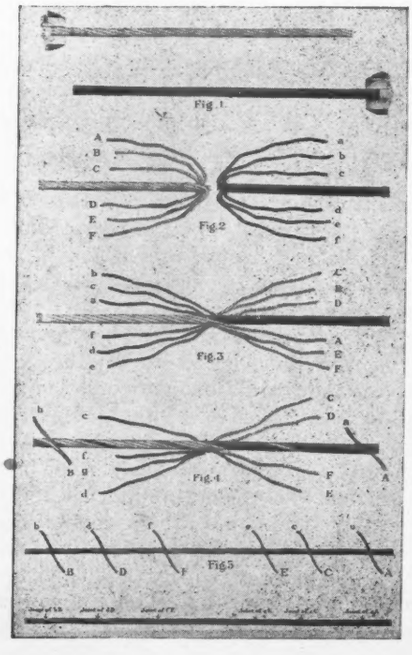
The following method of splicing wire rope is recommended by the American Cable Co. In splicing the two ropes, fasten the ends so that they overlap, allowing for a splice of 15 to 45 ft. as indicated in the foregoing table. For purposes of explanation we will assume a 30-ft. splice. First wrap or tie the ends securely with iron wire 30 ft. from each end, then unlay all strands 15 ft. as shown in Fig. 2 of the accompanying plate, cutting away the hemp core to permit bringing the two unstranded ends together so that the strands will interlock as in Fig. 3.

Take strand *a* and unlay it until the wire binding is reached and in the open groove place strand *A*. Lay *A* in tightly as shown in Fig. 4, making the twist agree exactly with twist of the open groove. Proceed in this way until all except 2 ft. of *A* are laid in and then cut off *a* and *A*, leaving the ends about 2 ft. long. Now unlay strand *B* in the opposite direction and in its place put strand *b*, stopping the ends of the rope in position corresponding to *A*, Fig. 4.

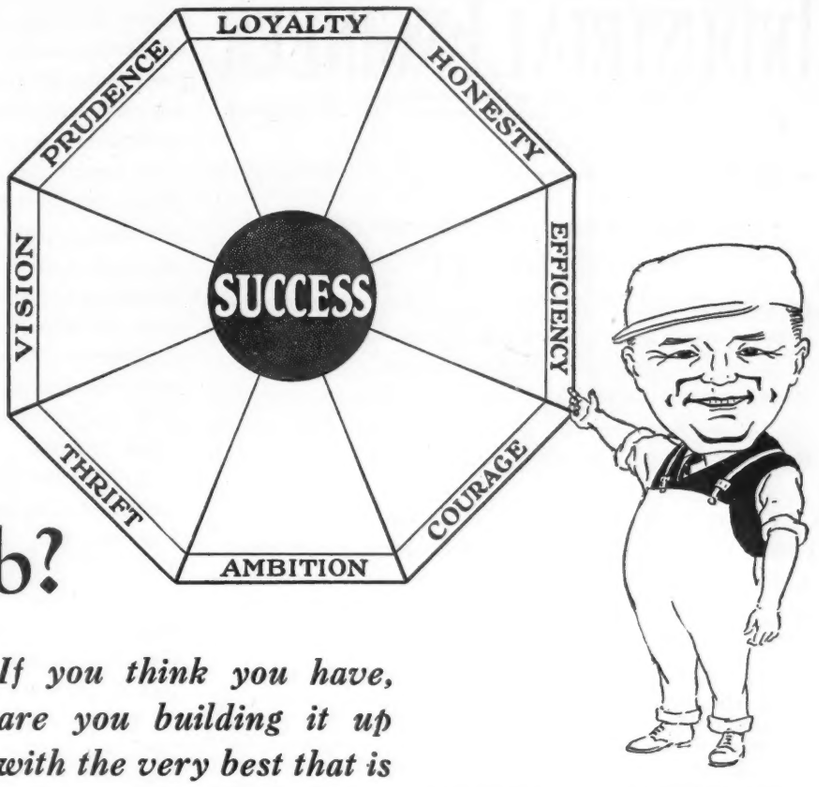
Subsequently *c* will be replaced by *C*, but this should be stopped 6 ft. short of the junction of *A* and *a*, as shown in Fig. 5. Similarly, *D* should be replaced by *d* and the end stopped 6 ft. short of strand *B* and *b*.

Proceed similarly with *E* and *e* also *F* and *f*, stopping the ends 6 ft. short of *C* and *c* and *D* and *d* respectively.

The rope will now present the appearance shown in Fig. 5 and the only remaining step is to tuck in the ends in such a way that the diameter of the rope will not be increased where the ends are tucked in. This is done by removing the hemp center and putting the ends of the strands in the place previously occupied by the core. To do this, it is first necessary to open or untwist strands *A* and *a* so that the hemp center can be seized with a pair of pliers and pulled out. Then a marline spike is inserted to keep the gap open. After starting the loose ends into the space left vacant by the hemp center rotate the marline spike to force strand into place.



These illustrations show the different steps in splicing a wire cable.



Have You A Good Job?

If you think you have, are you building it up with the very best that is in you?

NOT long ago when calling on the Chief Engineer of a large plant and waiting in his office while a factory signal gong was locating him for me, I chanced to see on the wall of his office a real message. This message is reproduced in its essential details in the accompanying diagram and has helped me to understand this fellow, whom I have come to know well and admire. There were no other hangings or decorations in that office and the above diagram took up a space about 3 ft. square. Under it appeared this comment:

"Have you a good job? Until you get a better position the one you hold is the best there is, and it deserves the best you can give it. Better workers always get better jobs."

This man employs many men and he is their boss in every sense. He exercises his authority not by force or fear, but by his own ability to do things and the way he goes at them. He does not stand on the sidelines and watch the game: he gets into it and while he is the leader, he knows how to place responsibility and build confidence in assistants that he can depend upon.

The above diagram tells a lot about this fellow, and by talking with him and his principal assistants you quickly get the impression that his is not a one-man job, but a job built by him around several men whose vision and ability have grown with the work and responsibilities that they have taken on as a group. Moreover, when you talk with his men alone they do not give you the impression that they are the whole thing, but you are impressed with what they know about the work they have in hand—not just a part of it, but the many related details. When it comes to arriving at a decision, however, then it is that the leadership of the boss comes in, for in every case when I have been interested and present, these men bundle up their facts and figures, plenty of them and complete in all details, and consult with the boss. At these times he seldom has to request that missing data be secured, for it is all there and they need no assistance in gathering in the facts. What they want and what they get freely is help in analyzing the problem at hand and arriving at its best solution. As a result of this procedure there are few misfits in this plant, and every one seems to be proud of that fact.

And so from this plant and its operators we can draw the conclusion that success in work, or success in ambitions is the result of a definite plan, consistently pursued and carefully worked out. Back of and along with this success must be certain fundamentals which I think are well laid out in the above diagram with its eight elements making up the wheel of success. Whether by intention or not, you will note that on the top, bottom and two sides stand Loyalty, Ambition, Vision and Efficiency, tied together by Prudence, Honesty, Courage and Thrift, with all revolving around or contributing to SUCCESS.

The more you study this diagram and think about the way it is made up, the more interesting it becomes. Try it!

Practical Pete

INDUSTRIAL ENGINEER
Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories
G. A. VAN BRUNT, *Managing Editor*

One More Reason for Standardizing General-Purpose Motors

INDUSTRIAL ENGINEER has often commented on the necessity for motor standardization. The steel industry has realized it for some time and has taken steps towards obtaining standardization of mill-type motors, as was reported in the June and July issues. But this movement takes no cognizance of general-purpose motors.

A letter from one of our readers, who is Chief Electrician in one of the 25 plants operated by his company, states what may be an extreme case, but nevertheless one that is characteristic of many plants at the present time. He says:

> "In the plant at which I was formerly stationed, there are some 240 motors—*of which no two are alike*—manufactured by 17 different firms. The stock of repair parts is so large that it cannot easily be imagined. In the course of time we expect to work this number of motors down to those of three or four manufacturers, but for the present it is necessary to operate the 240 mismates."

The troubles of the Chief Electrician in such a plant can be readily imagined. The crime, however, must be laid at the door of the man who specified motors from 17 different manufacturers. Either he carried to extremes the desire to try something new, or was unduly influenced by the price offered by some manufacturer to introduce his motor. Until manufacturers are able to standardize their motors, it will be necessary for users to limit their motors to two or three, and preferably less, different makes.

The Best Time to Fight Fire Is Before It Starts

MOST of us would admit, if we were asked about it, that fire is an ever-present and apparently ever-growing menace, but in the rush of the days' work we are inclined to grow careless and overlook some of the precautions that are essential. There is, consequently, need of calling attention from time to time, to the importance of cleaning up our plants, inspecting firefighting equipment to make sure that it is in good condition, and so on.

Fire Prevention Week, Oct. 3-9, was inaugurated for this purpose, and it is safe to say that proper observance of it may be the means of saving millions of dollars worth of industrial property.

The best way to fight fire is not to let it get started; a plant may be doomed to destruction within a few minutes after a fire breaks out. Many fires start in accumulations of inflammable material, such as waste paper, shavings, dust, and the like. Oily rags are an especially dangerous fire hazard. Preventing the accumulation of such material is a matter of plant housekeeping that should receive careful and continuous attention.

If inspiration is needed, take it from Fire Prevention Week and inspect the electrical equipment and wiring, particularly extensions and temporary installations, to make sure that they are safe from the standpoint of fire hazard, as well as safety to the workmen. Carefully check the condition of all firefighting and protective equipment. Otherwise, injuries or deterioration that will make such equipment useless, may go unnoticed until an emergency arises; then it will be too late to make repairs.

Go over the plant from end to end, clean out all rubbish, and eliminate any potential or actual fire hazards that you find. After the plant has been put in good condition, from this standpoint, see that it is kept in this condition. Then you can feel that you have done your part in protecting your plant or your job, and in reducing our annual fire loss of more than one-half billion dollars.

Do You Know How Much Energy Is Wasted By Your Power Drive Equipment?

NOT long ago the management of a large industrial plant was faced with a serious power shortage at the height of the busy season. The factory power plant was in good condition, but it was overtaxed by the growing demand for power. Accordingly, after considerable investigation it was decided to install a new boiler, engine and generator, at an estimated cost of more than $25,000.

A new Chief Engineer took up his duties just before the order for this equipment was placed and two or three days' investigation convinced him that it was not needed. He found that power was being wasted everywhere, in a multitude of ways. After considerable discussion he received permission to make some changes he had proposed, and the order for the new boiler and other equipment was held up.

First, he installed anti-friction bearings on every lineshaft in the plant. Following this, a large number of countershafts were eliminated, some old equipment was discarded and new purchased, and other changes made that reduced the friction load to a fraction of its former value. Then direct wastage of electrical energy was attacked. Idle operation of motors and machines was strictly forbidden. Likewise, burning of lights when not needed was stopped. And so on through a long list of the various ways in which power may be wasted, in small amounts as well as large. As the result of these economies the power plant was able to carry its load without difficulty, and with no expenditure for new equipment.

There are plenty of industrial plants today in which

there are fine opportunities to save power and cut operating costs by the application of good sense and sound engineering, supplemented by the authority to purchase equipment that is modern, efficient and well suited to the service conditions. Frequently, these opportunities are entirely overlooked, unless some crisis makes decisive action imperative, as in the above case. However, if power is purchased, there is not likely to be a shortage of this to serve as the stimulus to investigation and constructive thinking on how operating and maintenance costs can be reduced and the operating efficiency of power drive equipment improved.

It is hoped that every industrial executive who is concerned with plant operation will find that stimulus in this issue of INDUSTRIAL ENGINEER. It has been planned for that purpose.

Don't Leave the Lighting System Out of Your Winter Preparations

THE winter months, with their short days and long periods of darkness necessitating artificial light, will soon be with us. Now is the time to put the lighting system in order for the early morning and late afternoon periods when it will be needed. In particular, maintenance attention at this time will prevent much trouble and expense later, when the weather makes it difficult to get at outdoor lights and lights in semi-closed buildings. Also, a survey of what lighting is required may prove of decided value.

Too much light is something that is practically never found in an industrial plant. A careful investigation will probably reveal many places where more illumination would increase production or cut the cost of operation. Possibly some extensions have been added to the plant during the summer months. Have the lighting requirements for these locations been given careful attention?

Replacements of lamps should be made before a lamp burns out from old age. Typical performance curves on commonly-used sizes of lamps show that after 500 hr. use, the lamps give only 90 per cent of the light output that they do when new. Likewise after 1,000 hr. use they deliver approximately 80 per cent of the light given when new, while after 2,000 hr. use, the light delivered is only 70 per cent of its original value. The useful life of a lamp is considered to be 1,000 hr., but under conditions more severe than the laboratory in which the foregoing figures were compiled, the useful life would be even less.

Only a few weeks ago the eighth reduction of Mazda lamp prices since 1920 was made. Prices of these lamps are now 44 per cent below the 1914 prices. This in itself is still another reason why lamps should be replaced oftener.

If cost of operation is one of your bugbears, an investigation and overhauling of your lighting system may easily show places for cost cutting.

Replace Obsolete Control Devices With Modern Equipment

THE use of electric drive in industry is now quite commonplace and is the initial step in operating efficiency. However, there are very few plants where increases in production, reduced costs, increased safety, or decreased maintenance expense cannot be effected by replacing obsolete control apparatus with modern control equipment that is specifically designed to meet certain operating conditions.

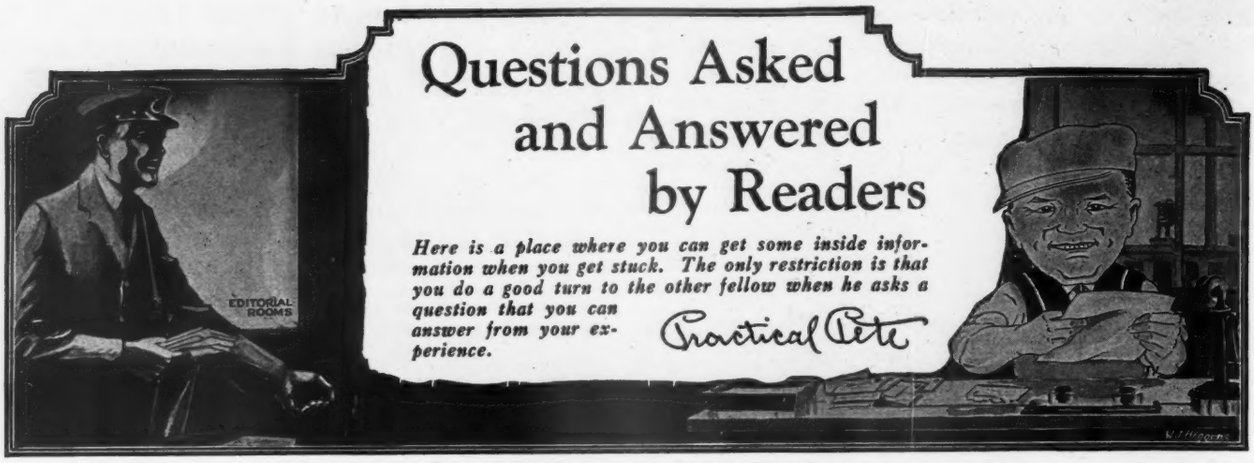
For instance, a 75-hp. motor used to tilt a Bessemer converter in a steel mill, was controlled by an old type of manually-operated controller. Considerable care was required of the operator, in gaging the limits of travel, and when a change of operators was made, some time would elapse before the new man became familiar enough with the method of handling the controller so as to tilt the converter in the shortest possible time without causing any spills.

After study of the problem by a control expert, an automatic controller was installed with limit switches at each end of the travel. The control is now operated by simply moving a small master switch handle from one position to another, whereupon the motor is automatically started, accelerated, and stopped at the proper position without any further effort on the part of the operator. The time saved, and the saving from spills formerly encountered, have paid the cost of the new controller in a few months.

In another case a winch operator and two men were required in a coke plant to operate a manually-controlled, motor-driven winch which was used for moving hopper bottom cars while they were being loaded with coke. Substitution of a car haul winch automatically controlled from a master switch at the coke screen operator's hand eliminated the winch operator and his two assistants and at the same time secured better loading of the cars because the screen operator could regulate the car movement to better advantage. The saving made by this installation paid its cost in less than a year.

A good example of the safety features of modern automatic control is the use of dynamic braking that can be applied in an emergency to prevent injury to workmen on candy pulling machines in candy factories, kneading machines in macaroni factories, and on rubber calenders in rubber mills. In case of trouble, any workman or person in the room can push any stop button and dynamic braking will bring the machines to a quick stop. This method of stopping machinery by merely pushing one of the conveniently located buttons has often prevented serious injury to workmen.

With high wages, and with investments in machinery as well as interest charges hardly declining, isn't it worth while to get a greater return per man or per machine? Modern electric control will help you in this regard. What others have done in the way of speeding up production and cutting operating costs you also can do.



Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete

Who Can Answer These?

Data for Building Auto-Transformer.—I wish to build an auto-transformer for use on 110-volt, 60-cycle current. This auto-transformer should have a capacity of 15 amp. and should have taps for voltages of 10, 20, 30, 40, 50, and 80 volts. I had planned to use a core made up of iron wire. Will this work satisfactorily? Can some readers give me the correct dimensions of the core that should be used, the size of wire, and the number of turns of wire that will be required. I shall appreciate your help.
Bayonne, N. J. E. J. M.

* * * *

Method of Ventilating Baking Oven—We are about to build an oven to be heated by electricity, which is to be used for baking coils and armatures. The oven is to be 9 ft. long, 6 ft. wide and 6 ft. high, and is to be placed out of doors. Can some reader tell me what is the proper way to provide ventilation for this oven? Any suggestions that readers can give me on this subject will be very much appreciated.
Fairmont, W. Va. R. M. F.

* * * *

Using Large Diameter Pulley on Motor.—Is it practicable to use a 20-in. pulley on a 25-hp., 750-r.p.m. motor? This would result in a peripheral speed of the pulley of 3,926 ft. per min. Would this be good practice? What objections would there be to using this size of pulley on the above motor in view of the fact that the motor manufacturer does not recommend a pulley of this diameter? Can some reader tell me what types of pulleys I could use or could not use in this case?
Toledo, Ohio. F. H.

* * * *

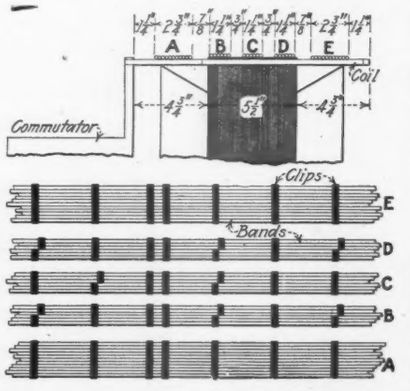
Cause of Fuses Blowing on Transformers.—During a recent violent lightning storm, the fuses were blown on one of our 10-kva., 2,300/220-volt, single-phase transformers. This transformer supplies a small, lighting distribution system. The transformer is protected by a pole-type lightning arrester. After the storm was over the fuses were replaced and the transformer operated satisfactorily. I shall appreciate any information that readers can give me on what caused these fuses to blow. I will be very much indebted to any reader who will advise me on this subject.
Wichita, Kan. Z. F. D.

* * * *

Trouble with Rewound Armature—I rewound a 5-hp., Crocker-Wheeler, armature which had 43 slots, and 129 commutator bars, each coil having 4 turns of 3 No. 14 d.c.c. magnet wires wound in parallel. The coil pitch was 1-and-10 and the lead pitch was 1-and-65. The armature tested clear of grounds, shorts, etc., but a bar-to-bar test with a millivoltmeter showed the following variations in readings: normal—high—low—high—low—normal—high—etc. I spanned about 12 bars in making this test. When assembled in its frame, the armature would seem to lock and would turn in jumps. The top leads were raised and tested for shorts, but everything tested clear. It was tried again with no better results. A duplicate of this armature was put in the same frame and it ran perfectly. The defective armature was then stripped and was found to be wound correctly and each coil was examined for the correct number of turns and cross-section but the coils were found to be O. K. Can some one tell me what the trouble was?
Iola, Kans. G. E. G.

* * * *

What Causes Armature to Throw Core Bands?—We are having trouble with the bands on an armature of a 75-kw., 2,400-r.p.m., 230-volt, 200-amp., four-pole, compound-wound turbo-generator. On account of a breakdown the coils were removed from the core, reinsulated, replaced, and connected as before. The winding was then tested with a growler and also a millivolt drop test was made. Next the five steel bands were installed as shown in the diagram. Each band is separate from the others and is



thoroughly soldered, with sheet copper reinforcing clips placed at six equi-distant points around the core, except at the start and finish of the band, at which point two copper clips were placed close together. After fitting the bands and again testing the winding, the armature was replaced and brought up to speed with the field circuit open. The field circuit was then closed and when the generator voltage rose to approximately 100 volts (less than half rated voltage), the bands became so hot that the solder loosened and the bands were thrown off. The airgap was ample, so that the bands were not striking the pole pieces. Furthermore, there was absolutely no indication of heating or other trouble in the winding itself. Will some reader please tell me what causes this armature to throw its bands? Is the trouble caused by having more than four equally spaced sets of copper clips around the periphery or by having two clips together, or both? Any information that readers can give me as to what is causing my trouble will be greatly appreciated.
Richmond, Va. W. H. E.

Answers Received To Questions Asked

Use of Non-Metallic Gears—I wish that our readers would give me their experience with the so-called non-metallic gears. We have several gear drives which wear rapidly, due to irregular loading, and soon become noisy. If I should use non-metallic gears would I have to use pinions with wider faces, and also have to replace the present gears with others having wider faces? If so, approximately how much wider would the faces have to be?
Des Moines, Iowa. J. F. K.

I would recommend that J. F. K. use a rawhide drive pinion of the same dimensions as the original one. It would seem to me that the gears which J. F. K. used were not lined up properly; otherwise, they would not wear out so rapidly. I believe that he will find the rawhide pinions to be very quiet in operation. Only one of the gears that mesh together needs to be rawhide.

The inherent resilience of rawhide enables this gear material to absorb the shock of tooth impacts and is responsible for the comparative absence of wear, and for quiet operation.

Chief City Electrician, Woodward, Okla. H. J. ACHEE.

* * * *

As J.F.K. undoubtedly knows the speed of a set of gears has a great deal to do with the amount of noise that they make in operation. The depth of mesh also influences noise. For quiet operation, gears should be mounted so that there is very little backlash. When installing gears some millwrights recommend using a piece of ordinary writing paper for ascertaining that the mating gears are at the proper centers and do not bind nor ride too loosely. The gears should be mounted so that the paper may be run through without being torn or deeply indented, when the gears are revolved by hand. The size of the gear is another factor which must be taken into consideration with the speed if the drive is not to be unreasonably noisy.

I believe that rawhide pinions could be used with the present gears, provided the pressure per inch of face of the pinion does not exceed 250 lb. If these pinions have bronze flanges the pressure may be safely increased 25 per cent. GRADY H. EMERSON.
Birmingham, Ala.

In reply to J.F.K.'s question, non-metallic gears made from Bakelite Micarta D are generally considered equally as strong as cast-iron cut gears. Micarta gears may be substituted for steel, cast-iron, or bronze cut gears, having the same dimensions as the metal gears.

In some cases, non-metallic gears have not given satisfactory operation from the viewpoint of noise and economy. Investigation has usually revealed that this is due to some of the following causes: Misalignment, improper or insufficient lubrication, and wrong design. Micarta gears should be lubricated with a light grease or heavy oil; they should operate with metallic cut gears, and have a shaft bearing in the bore of at least one-fourth of the pitch diameter of the gears.

Generally, no metal endplates or shrouds are required, but in special cases where some noise may be sacrificed for additional strength, metal shrouds are used. In such cases, the shrouds are included in the working face of the pinion meshing with the metal gear. The writer has used pinions of this construction for additional strength where certain limitations prevented any increase in the width of the face. These pinions compared favorably with all-metal pinions in operation and life.

E. H. LAABS.
Engineering Dept.,
The Cutler-Hammer Mfg. Co.,
Milwaukee, Wis.

* * * *

I presume that J.F.K. in his inquiry on the use of non-metallic gears, means the newer Fabroil or Micarta gears. We have used a number of these, especially for motor pinions, with very satisfactory results. In accordance with the makers' recommendations, we designed these gears by using the Lewis formula constants for cast iron and making the face about four times the circular pitch, as is usual for cut gears and, possibly, using a slightly coarser pitch than is customary with steel motor pinions. We are operating these gears loaded well up to their rated capacity and they have not shown any signs of wear or deformation. Because of these favorable results, we are inclined to believe that the data furnished by the manufacturers for the design is correct.

Bulletins on these gear materials, which contain much valuable information on the design of such gears and also include tables of desirable pitches and horsepowers transmitted, for simplifying the work of calculation, are furnished by the General Electric Co., Schenectady, N. Y., and the Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa., the manufacturers of the two materials mentioned.

Our experience with rawhide and vulcanized fiber gears has been that they are, as given in the reference books, considerably weaker than cast iron so that per horsepower transmitted, the Fabroil or Micarta gear will make a cheaper drive, because both the silent pinion and the accompanying gear can be smaller.

H. D. FISHER.
Plant Engineer,
New Haven Pulp & Board Co.,
New Haven, Conn.

Unfortunately, the information given by J.F.K. is not sufficient to make any definite recommendation as to the use of other materials and gear tooth widths. If the horsepower transmitted, the diameter and speed of the pinions, and whether they were made of cast iron or steel were known, some direct information could then be given in regard to the possibility of substituting some of the various types of non-metallic gears for the metal gears now used.

Up to the last decade, when the research departments of two big electrical companies developed a gear material from cotton sheets that were treated and compressed under enormous pressure, the chief non-metallic gear material was rawhide, a material that has served acceptably in drives ranging from small machinery to street car motors, pumps, and so on. Data on these new non-metallic gears (sold under trade names) may be obtained from their makers, but it should be remembered that an arbitrary substitution is not a guarantee of freedom from the present troubles.

These troubles go back to gear application design. It is well known that a gear may not wear well even though its individual teeth are strong enough to carry the load placed upon them. The remedy in such a case is to use wider faces. An old rule-of-thumb check on gear teeth has been to make the width of the tooth, in inches, at least $4\frac{1}{2}$ times the number of horsepower transmitted divided by the pitch diameter of the gear in inches. The tendency toward high motor speeds has made it necessary to use better materials because cast-iron pinions, even though they had been designed according to this check, which was for ordinary machinery, would not stand up at the high speeds. As a result, pinions made of untreated and case-hardened steel and non-metallic compositions and materials of various kinds have been introduced to carry the increasing loads without increasing the width to undue sizes. In the street car field, and in some industrial work, hardened tool-steel pinions have given double the life of the soft steel ones so long in vogue.

J.F.K. says the pinions "become" noisy which implies that they were quiet at the start. It is evident that the load is too great and the speed too high for the width of face. At high peripheral speeds, 1,700 f.p.m. and over, unhardened metal pinions wear rapidly, due to the shock of contact and all gear formulas take this into consideration. It is at such velocities, and beyond, that the rawhide gear found favor because it cushioned the shock and was less noisy; it has been customary when using the best quality of rawhide to disregard peripheral speed altogether in designing gears.

According to the Lewis formula for gear teeth, rawhide teeth should have $1\frac{1}{2}$ times the width of cast-iron teeth and 3 times the width of teeth made from 0.30 per cent carbon steel, if each is to transmit the same power.

J.F.K. would be no better off if he used non-metallic pinions unless he changed to new gears also, because the load-carrying area of the pinions is limited by the width of the gears. Also, it is very likely that the gears have worn so that they will continue to cut pinions as fast as new ones are installed. Good cut teeth roll, properly meshed, upon one another, but as soon as they wear out of shape the points in contact slide on each other and the resultant friction constantly wears off particles of metal.

J.F.K.'s troubles, however, may not be entirely due to too narrow faces. In many cases, the motors and the shafts they drive are not lined up parallel in both horizontal and vertical planes. This results in a condition which will start tooth wear the moment the switch is closed.

Where a motor is insecurely mounted or supported, or the driven shaft is loose in its bearings, misalignment and the same wearing conditions will result. When two gears do not line up the contact is at one end only, even if the gear and pinion are several inches wide and the amount of contact cannot be increased until that end has worn down. The wear, however, does not follow the theoretical shape of correct teeth, with the result that there is constant friction and noise throughout the shortened life of the gear and the pinion that meshes into it.

There is but one correct meshing position for a pinion in its gear. Owing to the difficulty of lining up motors, the best check is to use slips of paper or thin metal between the teeth before running the drive at all. These slips have to be rolled in place by turning the motor over by hand. They should "pull" the same in four positions; that is, at the top and bottom of a given tooth, at both ends.

In irregular loading J.F.K. has hit upon one of the most common troubles in the realm of transmission but withal one which is often given the least study. Irregular loading is often the cause of a noisy drive; to overcome this herringbone gears are being substituted in many cases. These gears, from the nature of their tooth angle, run quieter because backlash is better taken up than with ordinary spur gears. With intermittent loads, much of the noise is due to the rebound and does not result from contact between oncoming teeth.

The writer had a case of a motor drive on a metal planer that could not be silenced by gears, but was effectively silenced by use of a Morse chain and a compensating driven sprocket. On this installation a 6-ton table load, together with four large pulleys traveling at about 5,000 f.p.m., had to be reversed several times a minute. We had no trouble with gear tooth wear; however, the noise was so bad that the planer had to be stopped in order to use the telephone in a booth in the office about 100 ft. away. Even though we installed new pinions and new gears, then non-metallic pinions and new bearings all around, none of them had any effect upon the noise. However, the chain drive was so quiet that a whispered conversation could be carried on alongside the machine itself.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Paralleling Open-Delta-Connected Transformer Bank With Closed-Delta Bank.—I would like to obtain the experience of some of our readers in regard to parallel operation of an open-delta-connected bank of transformers with one or more closed-delta-connected banks of transformers. Under what conditions is such operation possible? How does the load divide between the several banks of transformers? How is the capacity affected of both the open-delta bank as well as the closed-delta bank? If we have two banks of closed-delta-connected transformers operating in parallel on both the high- and low-tension sides, will these two banks of transformers continue to operate satisfactorily and divide their load in accordance with their capacity, if one transformer is cut out of one bank so as to make an open delta connection? In this particular case, all of the transformers are of the same size, voltage, ratio, reactance, and were made by the same manufacturer.
Wilmington, Del. H. E. H.

In answer to H. E. H's inquiry I would say that from actual experience I have found the operation of transformers connected in this manner to be satisfactory.

In his book, "Transformer Practice," Taylor says that the removal of one transformer of a closed-delta group results in a very slight unbalancing, due to the fact that the impedance in the middle main being the algebraic sum of the impedances of the two outside mains, the resulting capacity is $1 \div \sqrt{3}$ or 58 per cent of the original capacity.

I know of a bank of three 500-kva. 25,000/440-volt transformers that is paralleled on both primary and secondary sides with a bank of two 200-kva. transformers which are connected open delta.

These banks supply power to four rotary converters and the load is divided in accordance with the capacities of the transformer banks.

Chief Engineer, PHILIP N. EMIGH.
The Mountain Water Supply Co.,
Indian Creek, Pa.

* * * *

The writer has operated transformer banks in the manner indicated on a number of occasions without any apparent serious results. In one particular case two 450-kva. banks, each made up of three 150-kva. units, but with one bank having one transformer cut out, were so operated for more than a month. Tests on the division of load between banks, made by putting a portable split-core transformer over each transformer lead, did not show any values exceeding the normal rating of the transformers. Theoretically, there might be some objections to this practice from the standpoints of regulation and voltage unbalancing between lines but, practically, the operation can be carried out. Naturally the capacity of the open-delta-connected bank will be reduced in proportion to the total capacity. It is recommended that tests be made in each instance when such operation becomes necessary.

C. OTTO VON DANNENBERG.
General Engineering & Management Corp.,
New York, N. Y.

* * * *

In reply to H. E. H., I would say that transformer banks can be operated in parallel if the following conditions are fulfilled:

(1) The ratio of transformation on all the banks operated in parallel must be the same. This means that the proper taps must be connected to the transformer terminals inside the transformer case.

(2) Units of the same capacity must have the same characteristics. This means that the reactance and resistance drops must be approximately the same.

(3) The polarity of the banks must be the same. Units of different polarity must be connected so as to obtain equivalent polarity.

(4) Phase rotation must be the same. A motor connected to the corresponding leads of all the banks must rotate in the same direction.

Transformer banks connected in open delta and operating in parallel with transformer banks connected in closed delta will divide the load in the ratio of 1.73 to 3. This means that with a total load of 100 kva. on two banks operating in parallel, one connected in open delta and the other in delta the proportion of the load carried by the closed-delta bank will be $(3 \times 100 \div 4.73 = 63.5$ kva. or 63.5 per cent of the total load and the load carried by the open-delta bank will be $(1.73 \times 100) \div 4.73 = 36.5$ kva. or 36.5 per cent of the total. A. NOEPPEL.
Chicago, Ill.

* * * *

Proper Foundation for Alternator.—(1) We are going to install a 133-kva., belt-driven alternator in the near future, and I should like to know how to make a suitable foundation for it. We are thinking of using a wooden framework. Is this alternator too large for such a foundation? I should like to know what type of foundation readers would recommend for this alternator, and also how the foundation should be made. (2) When the distance between pulley centers of the alternator and engine is long should the alternator foundation be heavier than when the machines are close together? How should the alternator be fastened to the timbers or other types of foundations that are recommended? I shall greatly appreciate any information that readers can give.
New Orleans, La. O. C. H.

Referring to O.C.H.'s inquiry regarding the foundation for a 133-kva., belt-driven alternator, I would say that the data furnished are rather indefinite as to the speed, pulley size and location, although some general information may be of assistance.

Unless local conditions make concrete or brick foundations impractical, I would not recommend a wood foundation as it is hard to get a good level bearing without the use of loose wedges. The softness and give in wood, together with a continued drying process, make it difficult to keep the machinery tight on the foundation and thus prevent vibration. Most of the motors up to 125 hp. that we have mounted on wooden foundations have been installed only for temporary service. As the wood shrinks and wears down, it will be necessary to tighten the foundation bolts periodically, in order to prevent the machines from vibrating. A belted machine should be installed on a sliding base so that the belt may be conveniently tightened, when necessary.

If the foundation is to rest on earth, I would recommend a concrete foundation which is about 1 ft. larger than the base of the machine. The base of the foundation should be set into the earth about 3 ft., or if there has been a recent fill dig down to solid earth. The top of the foundation should be built about 1 ft. above the floor level in order to keep the machine up out of the dirt and wet.

The lower end of the foundation bolts should not only have washers but should extend to within 6 in. of the bottom end of the foundation. The upper end of the bolts should extend through a pipe sleeve that is about 1 ft. long and 2 in. larger in diameter than the bolts. After pouring the foundation, the sliding base and machine should be set in the operating position and leveled high enough with iron wedges so that there will be plenty of clearance for about 1 in. of grouting. After lining up the machine, the base should be grouted in, being careful to fill in around the foundation bolts, in order to keep the base from shifting sideways.

It does not take an enormous foundation to withstand the belt pull of a motor or generator, but it is important to have the machine bolted down securely so as to prevent vibration.

Due to the fact that the arc of contact between the pulley and the belt is greater with a long belt than with a short one, it is likely that the total belt pull is slightly less with a long belt. Generally the difference in belt pull is not great enough to materially alter the size of motor foundation.

In fastening the alternator to the foundation, as has been described above, a standard sliding base as furnished by the maker should be used. Whether the foundation is of wood or concrete, through-bolts should be used in preference to lagscrews. In the event that a wooden foundation is used, through-bolts should be employed so that the foundation can be tightened up when necessary.

Much trouble with motors and generators can be eliminated, if a little more care is exercised when the machines are installed. H. D. FISHER.
Plant Engineer,
New Haven Pulp & Board Co.,
New Haven, Conn.

* * * *

Heating of Commutator on Rewound Repulsion-Induction Motor.—I recently rewound a G. E. single-phase ½-hp. four-pole type RI 110-volt repulsion-induction motor and am having trouble with it on account of heating. The commutator seems to heat first and in about two hours the motor gets so hot that you cannot put your hand on it, and it keeps on getting hotter. It does this when running idle. I have tested the commutator, armature, fields, and bearings and they seem to be O. K. The armature is well balanced. I used No. 16 d.c.c. wire in the rotor and main field and No. 18 in the compensating field. I shall appreciate any information regarding the cause and remedy of this condition.

In the September issue an answer to R. S. states that the trouble on a G. E. type RI single-phase motor is due to the short-circuiting device. I have had considerable experience with type RI motors, so wish to say that this has no short-circuiting device. Two sets of brushes are placed on the commutator, at opposite sides. One set is connected by a jumper, while the other set leads to the compensating field.

This set is, in all probability, the cause of the trouble in the motor. If R. S. will change these back, that is

reverse the brush connections to the compensating field and then adjust the brush setting to the best running position, his troubles will probably be over. This is a common mistake on these motors. If an ammeter is available, place it in the line and determine the load on the motor. Then reverse the compensator field and again read the ammeter. The connection giving the lower reading on the ammeter will be the correct one.

Buffalo, N. Y. WALTER M. RENNICK.

* * * *

Trouble from Static on Belt-Driven Machines.—We have about 200 sewing machines all of which are belt driven. The girls who run these machines complain that they frequently get shocks from them. I believe that this is due to static from the leather belts which drive the sewing machines. I shall appreciate it very much if some reader can tell me how to prevent this trouble. I have grounded the sewing machines but the trouble still continues. To what should I ground the machines so as to obtain the best results? How should the ground be made? I might say that the sewing machines are placed on wood floors in a room that is quite dry and warm. Would the use of rubber belts correct the trouble I am encountering? I should like to learn the experience of other readers on this subject.

York, Pa. P. C.

Answering the question by P.C., we remedied a similar case of trouble in the following manner. Upon investigation we found that the static did not come from the individual machine belts but came from a larger belt driving the countershaft. As a remedy we simply attached a piece of No. 14 wire to the ceiling directly over this belt, so that a nut which was attached to one end of the wire hung within an inch of the belt. The other end of the wire was attached to a sprinkler pipe for a ground. This arrangement proved effective and inexpensive.

Electrical Dept., W. S. Libby Co., Lewiston, Me. A. C. BARKER.

* * * *

My experience some years ago, before the guarding of belts was subject to state regulation as it is now, with a battery of belted Bliss presses knocking out heads for condensed milk cans, may be of assistance to P.C. The girl operators complained about the "electricity" in the belts and how it attracted their hair, particularly as they passed along the aisle near the belts. Almost any time, it would be possible to place a finger near one of the belts and see a ½-in. spark jump between the finger and the belt.

To remedy this condition we attached strips of copper to the frames of the presses, but insulated from them, and carried a wire from these strips to the steam pipes along the wall back of the machines. Each machine had its strip and ground wire. There were no more complaints after that.

Another advantage which we found resulted was the reduction in the loss from burned-out lamps in the drop lights for each machine. These lamps were close to the belts and in some way the static in the latter had a bad effect on the filaments (drew them to one side, we thought) and they would burn out in about a week. After the grounds were put on there was no more trouble with these lamps than with any other lights in the plant.

With the sewing machines in question, I believe that P.C. should ground the static before it gets to the machines. Presumably, this could be done by a grounded "busbar" running along under the bench and near the belts, or close enough to solder fingers to it, which would come near the belts, and in this way eliminate the static trouble.

DONALD A. HAMPSON.

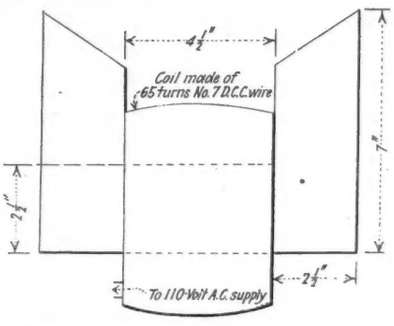
Plant Superintendent, Morgans & Wilcox Mfg. Co., Middletown, N. Y.

* * * *

Demagnetizing a Lathe.—I have a 24-in. by 10-in. selective head lathe, which is magnetized; at least, when any work is done on the lathe, the chips cause us trouble by sticking to the lathe tool and surrounding lathe parts. It is my opinion that the spindle of the lathe is magnetized. I shall greatly appreciate it if readers will tell me how to demagnetize this lathe. If it is necessary to use a demagnetizing coil, how big should the coil be, how many turns and what size of wire should be used? Also, how many amperes should flow through the coil? Is there any way that I can demagnetize this lathe without using a demagnetizing coil?

Beaumont, Tex. O. C. B.

In answer to O.C.B.'s question I would say that this trouble may be easily overcome by placing the magnetized parts in a magnetic field that is subjected to frequent reversals. This



Data for making growler that may be used to demagnetize metallic parts of machines.

can be obtained by placing the parts on a growler and then slowly moving the parts away from the growler while the current is on.

The accompanying sketch shows how I made a growler which may be used to demagnetize small machine parts. The core is made up from laminations of sheet iron of the shape shown in the sketch. Enough laminations are used so as to make a thickness of 2½ in. Sixty-five turns of No. 7 d.c.c. wire are wound on the center of the core. This is sufficient for operation from a 110-volt, alternating-current, power supply. For operation on 220 volts, use double the number of turns in winding the coil of the growler.

When demagnetizing parts, be sure to pull the parts away from the growler while the alternating current is still on. Turning the current off before the parts are pulled away has a tendency to magnetize them.

Chief Electrician, Premier Coal Co., Middleboro, Ky. O. C. UMBERGER.

Although not so stated by O.C.B. the lathe which he mentioned as being magnetized, may be motor driven. The motor mounting, in that case, may be of the kind that has the motor fastened to the top of the head casting or to a bracket that is integral with some structural part of the lathe. Such being the case, it would be possible for the motor to be defective or to have been damaged to the extent of a ground or leakage of sufficient current to turn some part of the structure into a weak electro-magnet and this would, of course, cause tools and chips to stick to the various parts of the machine and cause considerable inconvenience.

The fact that O.C.B. states that he thinks the spindle is magnetized leads me to believe that the lathe may have been used somewhere previously with a magnetic chuck attached to the spindle for some special manufacturing. These chucks operate on 110- or 220-volt circuits and some of them carry 5 to 10 amp., which is sufficient current to magnetize the machine (lathe) particularly if there happened to be a short. If this condition had existed for a long time, the residual magnetism in the lathe's mass would be of sufficient amount to cause inconvenience for a considerable period.

It is hardly conceivable that the lathe would remain strongly magnetized unless there were some undiscovered source of magnetism operating while it is in use. Ordinarily, it would be much harder to *keep* a lathe (or almost any other part) magnetized than to keep it demagnetized. A careful investigation of all wiring near the machine and a test for grounds will probably reveal the real cause of the trouble. To a slight degree, a high-speed driving belt might be a contributing cause. If such is the case, metal combs located near the belt and attached to a wire grounded to a water pipe might help O.C.B. out of his trouble.

DONALD A. HAMPSON.

Plant Superintendent, Morgans & Wilcox Mfg. Co., Middletown, N. Y.

* * * *

Where Should I Use This Kind of Wire?—Most manufacturers of wire for use in house wiring and in industrial plants make three kinds of wire: a Code wire, an intermediate grade and a 30 per cent rubber compound grade. I should like to learn from other readers whether they use all three grades around their plants and if so, the basis on which they decide the grade that shall be used for a certain application. Do you find any of these grades unsuited for industrial plant use? I shall appreciate any information that you can give me regarding the proper application of these three grades of wire.

Newark, N. J. B.S.

Referring to the question by B. S., code wire of the proper voltage should be used for all industrial power wiring. For lighting, open wiring in residences, signal and low-voltage work, the intermediate grade may be used, although it is not good practice if the wires are run in conduit. The 30 per cent rubber compound grade may be used on bell and low-voltage (50 volts and under) signal work and for open wiring on low-voltage lighting in dry locations. H. E. STAFFORD.

Electrical Engineer, Provincial Paper Mills, Ltd., Port Arthur, Ont., Canada.

Electrical Service

around the works

For this section short articles describing ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing, and emergency or special installations.

Unusual Method of Fishing Through Conduit By Using Conveyor Wire

THE use of a so-called conveyor wire for fishing through a new type of metal molding used for surface wiring solved a difficult problem recently. This molding has an oval cross-section so that the wires lie in a row parallel to each other. The size used on this job will hold only two wires, and had many sharp bends in it so as to follow the surface against which it was laid.

Ordinary spring-steel, fish wire would not do for this job for it was too stiff to go around more than one or two bends. The conveyor wire while being sufficiently stiff to enable it to be pushed through the conduit, was nevertheless flexible enough to go around as many as four 90-deg. bends at one fishing.

This conveyor wire is made by winding steel wire in the shape of a spiral spring, and is about ⅛ in. over-all diameter. It is quite similar to the spring wire belts used on some fractional-horsepower drives, and is widely used in newspaper plants as a belt conveyor for carrying the printed papers from the presses to the mailing department. It is from this use that it gets its name of conveyor wire.

Seeing this conveyor wire used for fishing through the flat metal molding mentioned above, suggested that it could be used to advantage for fishing through standard, rigid conduit. It will readily go through the smaller sizes of conduit and will go round sharp beds with ease. It is more easily carried around by the workmen as it can be rolled up into a small roll without danger of kinking. This is more than can be said of regular fish wire.

New York, N. Y. A. J. W.

Record Cards for Listing Power Drive Data

THE need of keeping a record of motors and other power drive equipment is well recognized, but the means of doing so are not standardized and in many cases the methods used tabulate incomplete data which results in the files being much less valuable than they should be.

The card shown in the accompanying illustration has been used with great success in our plant. The outstanding feature is the completeness of the record of all spare part information regarding the drive.

On the top line of the card are recorded the name of the drive and the department in which it is located. Following this is a place for the complete nameplate data of the motor. After this, spaces are provided for recording the rewinding data for the armature, stator, and rotor as well as the data for making up or reordering slip-rings, commutators, field coils, brushes, and brush-holders for the particular motor in question. Note that in each case spaces are provided for each essential part of the description required to make or order the desired part.

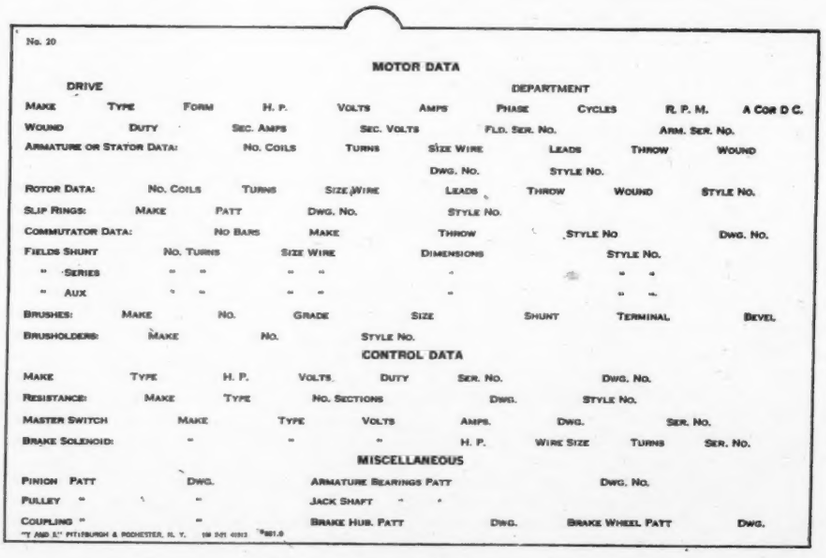
Following the motor data, spaces are provided for recording the nameplate data of the control used with the motor. There are also spaces for recording all information necessary for reordering controllers, resistance, master switch and brake parts.

The bottom part of the card is devoted to miscellaneous parts of the drive such as the pinion, pulley, bearings, couplings, brake wheels, and the like.

On the back of the card is a place for recording the loads as tested at various times. At the top is a place for indicating the sizes of instruments required, thereby saving time whenever a test is to be run to check the loading of the motor.

Chief Electrician, J. F. MURRAY.
Follansbee Bros. Co.,
Toronto, Ohio.

Here is a motor record card that gives a complete record of the motor and other parts of a power drive.


No. 20

MOTOR DATA

DRIVE — DEPARTMENT

MAKE TYPE FORM H. P. VOLTS AMPS PHASE CYCLES R. P. M. A Cor D C.

WOUND DUTY SEC. AMPS SEC. VOLTS FLD. SER. NO. ARM. SER. NO.

ARMATURE OR STATOR DATA: NO. COILS TURNS SIZE WIRE LEADS THROW WOUND

DWG. NO. STYLE NO.

ROTOR DATA: NO. COILS TURNS SIZE WIRE LEADS THROW WOUND STYLE NO.

SLIP RINGS: MAKE PATT DWG. NO. STYLE NO.

COMMUTATOR DATA: NO BARS MAKE THROW STYLE NO DWG. NO.

FIELDS SHUNT NO. TURNS SIZE WIRE DIMENSIONS STYLE NO.

" SERIES " " " " " "

" AUX " " " " " "

BRUSHES: MAKE NO. GRADE SIZE SHUNT TERMINAL BEVEL

BRUSHOLDERS: MAKE NO. STYLE NO.

CONTROL DATA

MAKE TYPE H. P. VOLTS DUTY SER. NO. DWG. NO.

RESISTANCE: MAKE TYPE NO. SECTIONS DWG. STYLE NO.

MASTER SWITCH MAKE TYPE VOLTS AMPS. DWG. SER. NO.

BRAKE SOLENOID: " " " H. P. WIRE SIZE TURNS SER. NO.

MISCELLANEOUS

PINION PATT DWG. ARMATURE BEARINGS PATT DWG. NO.

PULLEY " " JACK SHAFT " "

COUPLING " " BRAKE HUB. PATT DWG. BRAKE WHEEL PATT DWG.

"Y AND L" PITTSBURGH & ROCHESTER, N. Y.

1

TEST DATA

POT. TRANS. RATIO TO AMMETER COIL AMPS.
CUR. TRANS. RATIO TO SHUNT AMPS.
WM. POT. COIL VOLTS MULTIPLIER (X):
WM. CUR. COIL AMPS.

A.C. FORMULAE D.C.
AMPS.(I): A x X
WATTS. : W x X
V.A.: $\frac{A_1 + A_2}{2} \times E \times 1.732$
H.P.: $\frac{\text{WATTS.}}{746}$
WATTS.: E x I
H.P.: $\frac{\text{WATTS}}{746}$

E	A^1	A^2	W^1	W^2	Amps 1	Amps 2	Watts 1	Watts 2	Total Watts	Volt Amps	% P.F.	R.P.M.	REMARKS

Correction in "Determining Power Factor with Watt-Hour Meters"

A TYPOGRAPHICAL error appeared in the article by C. Otto von Dannenberg under this head on page 431 of the September issue of INDUSTRIAL ENGINEER. A formula for power factor was given as follows: Power factor in per cent $= 100 \times \frac{1}{2} \times \sqrt{(1 + X)^3} \div (1 + X^2)$.

This formula should have read, power factor $= 100 \times \frac{1}{2} \sqrt{[(1 + X)^3 \div (1 + X^2)]}$.—EDITORS.

Saving $740 in Equipping Yard Locomotives With Electric Headlights

IT BECAME necessary to equip our two yard locomotives with electric headlights in order to operate them on night shift at the plant with which the writer is associated. Due to the fact that this night work is to continue only during the current year, we hesitated to purchase the usual steam turbine headlight generator, as the cost was rather high. Such a unit would cost about $400.

The Electrical Department suggested the installation of a storage battery on each locomotive together with 6-volt headlights such as are used on automobiles. This suggestion was adopted and the necessary material purchased. Two spare batteries were purchased; so it was a matter of only a few minutes to remove the used battery twice a week and replace it by one fully charged.

A headlight was placed on each end of the locomotive. Double-filament lamps were used and connected so that when the front light is bright (32-cp. filament in use) the rear light is dim (2-cp. filament in use) and vice versa.

It was found that the batteries gave bright illumination for a period of three nights, so the batteries are now changed twice a week—on Monday and Wednesday. The batteries are charged from a d.c., 110-volt exciter which operates constantly in supplying field excitation for a large synchronous motor. A resistor is used to cut down the flow of current into the batteries. The entire cost of this installation was less than $60 for two locomotives. Turbine generator units would have cost at least $800 for the two locomotives; hence there was a saving of $740 obtained in using the method described.

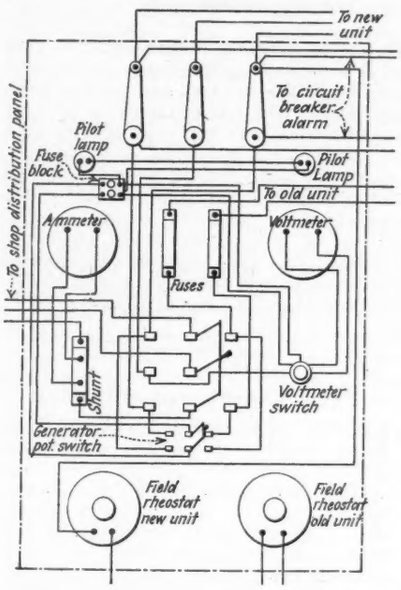
CHARLES A. PETERSON.
Chief Electrician,
U. S. Gypsum Co.,
Alabaster, Mich.

Layout of Panel to Control Two Generators

THE recent installation of a new, engine-driven generator in our factory power plant made necessary the construction of a special switchboard panel to accommodate both the new unit and the one it superseded. The old generator is now used as a stand-by.

The new unit is a 230-volt, 150-kw., direct-current Ridgeway generator of the three-wire type, whereas the old 75-kw. generator is of the two-wire type. The difference in types of generators made necessary the use of a three-pole, double-throw main switch with only two clips on the side which is connected to the old generator. The latter is protected by 400-amp. fuses, whereas the new generator is protected by an ITE circuit breaker of the three-coil type, the neutral calibration being 125 to 175 amperes. Two conditions are responsible for this arrangement: First, the fact that the new unit requires a circuit-breaker having a range of 600 to 900 amp., which would be more than 50 per cent overload on the old set; second, the old unit is used so rarely as to make the matter of an occasional blown fuse not objectionable from the standpoint of time lost or cost of fuses.

The Weston voltmeter, 0 to 300 volts, and the two pilot lamps are protected by the same set of 3-amp. fuse plugs. The voltmeter is connected to a small, double-pole, double-throw knife switch which enables it to be transferred from one generator to the other as required. This arrangement also makes it possible for the generator voltage to be adjusted to its proper value before the main switch is closed.



Either generator can be cut into service by throwing the double-throw switch to the proper position.

Inasmuch as the old two-wire generator is run only infrequently, fuses are employed for overload protection. An ITE circuit breaker is used to protect the new three-wire generator.

The voltmeter circuit for the new three-wire generator contains a Westinghouse drum-type voltmeter switch which makes it possible to read successively the voltage on each side of the neutral and across the outside mains.

The Weston ammeter, 0 to 1,000 amp. capacity, is connected to a shunt, and is calibrated to read directly. Special, slotted terminals are used to connect the shunt in the main circuit.

The circuit breaker alarm device described on page 37 of the January, 1922, issue of INDUSTRIAL ENGINEER is connected as shown in the diagram.

The switchboard panel is made up of four sections of 16-in. x 40-in. x 1½-in. purple slate, mounted on angle irons which are bolted to projecting angles embedded in the floor.

The cost of all the material used in the construction of the panel, including instruments, was $586.16. The labor cost was $70.43, which included laying out and drilling of the slate panels and angles, mounting and wiring of instruments, and erection of the board in the engine room. The field rheostats and old generator fuses are not included in the above cost of material because they were, in one case, on hand, and in the other the new generator rheostat was supplied with the unit.

Asst. Chief Engineer, J. M. WALSH.
Gurney Elevator Co.,
New York, N. Y.

European Practice in Laying Steel-Armored Cables

RECENT discussions in INDUSTRIAL ENGINEER give the impression that underground, steel-armored cables are not widely used in American industrial plants. In Europe, however, it is general practice to use them on voltages up to 15,000, which is usually the highest voltage to be found inside an industrial plant.

In order to obtain good results from underground cables, great care should be given to the installation, which should preferably be done by an experienced crew. The standard practice in Europe is to lay the cables in a trench 32 in. to 36 in. deep, and not less than 20 in. wide at the bottom. A layer of sand about 2 in. thick is first spread over the bottom of the trench, and the cables are then laid in and pulled straight by men placed at intervals. For long lengths of cable, this procedure requires a large number of men, but it has been found safer than mechanical methods of pulling for they usually endanger the life of the cable. After the cables are laid, a second layer of sand about 4 in. thick is placed over them. Bricks are then laid over the sand to indicate the presence of the cables and to prevent the workmen from injuring them when digging again later. The trench is then filled in.

Sharp bends should be avoided and when changing direction the inside radius of the bend should not be less than 12 times the diameter of the cable. Underground cables should not be installed during freezing weather, because if they are subjected to cold the jute or impregnated paper, which forms the insulation, will crack and later cause breakdowns to ground.

When two cables have to be joined together, each end is stripped of all the insulation and brought into a cast-iron junction box. The conductors of the same polarity are joined by a copper sleeve and soldered. After the conductors are spread apart, the ends of the box are firmly tightened, and the box filled with insulating compound.

In power houses and substations every cable terminal is provided with a cast-iron terminal box. The bare conductors are spread apart in the box, which is then filled with insulating compound, the leads coming out through porcelain insulators.

Cable manufacturers give data which indicate the allowable load (in amperes) for each type of cable according to its cross-section. When more than two cables are placed in the same trench it is advisable to decrease the rating in amperes given by the manufacturer in the ratio of 1 to 0.75.

If underground cables are properly handled, they will last for a long period of time. I have seen such cables, installed in 1902, whose double steel tape had disintegrated by rust, but which were still giving service.

P. VAN HERK.
Bressoux, Liege, Belgium.

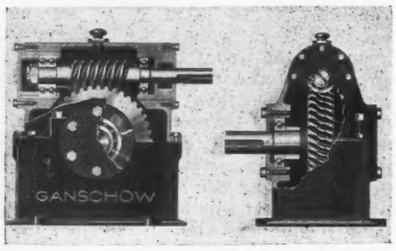
New Equipment

for plant operation and maintenance

Industrial plant executives concerned with the selection and operation of mechanical and electrical equipment will be interested in these new devices which are designed to improve plant operation or reduce operating and maintenance costs.

Worm Gear Speed Reducer

ANNOUNCEMENT is made by the William Ganschow Co., 18 N. Morgan St., Chicago, Ill., of improvements in the types of their fully-enclosed, worm gear speed reducers which have been placed on the market recently. Standard units are equipped with gears of special bronze which, it is



stated, give an increased load-carrying capacity. The worm is made of 3½ per cent nickel steel, which is hardened and ground all over.

Either ball or roller bearings can be fitted to the unit according to the service demands. The gear bearings are held in place by means of clamping plates, as in the duplex worm thrust bearing. The front radial worm bearing is free to float which compensates for expansion due to heat. The cast-iron housing forms an oil reservoir into which the gear dips.

Self-Start Squirrel Cage Motors

TWO new, improved types of self-start, squirrel-cage, induction motors have been announced by the Imperial Electric Co., Akron, Ohio, after two years of intensive shop and field tests on them.

According to the manufacturer, the high-torque, self-start motor, Type EH, will deliver 175 per cent of full-load running torque to start, which value will rise, after the motor begins to revolve, to a value approximating 250 per cent. This motor will keep down the inrush of current at starting within the limits established by the National Electric Light Association and can, therefore, be installed and started across the line with enclosed, safety, hand-operated switches or with magnetic switches actuated by push buttons, float valves, pressure regulators and other similar devices. Sizes larger than 5 hp. have a double squirrel-cage rotor and are intended for installations requiring very high starting torque.

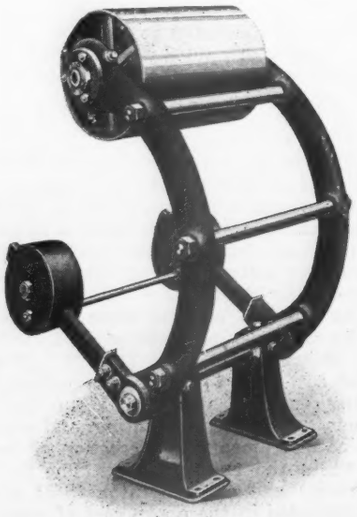
The Type EN self-start, normal-torque, squirrel-cage motor is designed to have a starting torque equal to that of a standard squirrel-cage motor connected to the highest tap on the compensator. The torque rises to a value in excess of 200 per cent of full load as the motor approaches its full speed, which characteristic is, according to the manufacturer, an improvement over self-starting motors whose torque drops off after the rotor starts to revolve. This type is especially adapted for installations requiring normal starting and high pull-out torques.

Short-Center Belt Adjuster

IDLER pulleys with swinging arms and weights to provide a constant, uniform tension on the flat side of the belt are announced by The Medart Co., Potomac and De Kalb Sts., St. Louis, Mo., under the name of Medart Short-Center Belt Adjuster. This device is shown in the accompanying illustration. It also shows the method of applying pressure to the idler pulley which takes up the slack in the belt.

The idler pulley may be equipped either with bronze bushings or anti-friction bearings. The pivot for the swinging arm may be adjusted. The idler pulley automatically swings between the driving and the driven pulley and is placed so that it will wrap the belt around the pulley, and thereby increase the arc of contact.

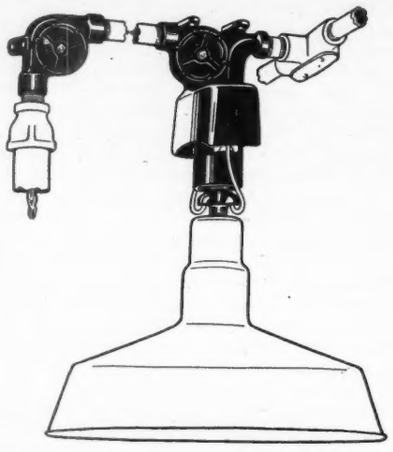
Some of the advantages claimed for this device are: elimination of belt slipping; increased life of belt; saving in floor space; the use of pulley ratios as high as 20 to 1 on short centers; and decrease of belt tension, with consequent reduction of bearing pressure.



Safety Lowering Switch

A NEW model safety lowering switch has been placed on the market by the Thompson Electric Co., of Cleveland, Ohio. This device has been developed for disconnecting and lowering lighting fixtures that are located in places which are exceptionally dirty. It differs from previous models of the safety lowering switch, in that there is no external opening in the sheave housing to admit dirt or corrosive elements. The galvanized sheave wheel is inserted through the side of the housing, making it easy of inspection without disturbing the installation in any way.

Another new feature is that provision is made whereby the conduit for inclosing the chain, and also the conduit for inclosing the wires, can be screwed straight into the sheave housing on the



ceiling or girder line, thereby making the lowering switch an integral part of the conduit system. When placed at right angles to a line of conduit, as shown in the accompanying illustration, a T-shaped conduit fitting and a short nipple will serve to bring the wires into the hanger.

Inclosing the chain in conduit is important, for three reasons: First, the chain will be safeguarded against accidents from contact with belting or other moving apparatus, even though it extends directly through a dangerous zone. Second, the chain will be protected from corrosive elements. Third, it greatly improves the appearance of the installation.

Use of this new model of lowering switch will naturally call for the use of the totally-inclosed corner pulley No. 149, shown in the accompanying illustration, which provides for turning the direction of the chain through a right angle.

Sign Illuminator

A SIGN illuminator made entirely of cast aluminum alloy and designed to thoroughly illuminate a standard 10-in. by 14-in. enameled sign, has recently been placed upon the market by the Nichols-Lintern Co., 7960 Lorain Ave., Cleveland, Ohio. This illuminator is particularly designed for use in industrial plants for illuminating danger signs. Although designed for a standard size of sign it can be readily

altered to illuminate signs of other dimensions.

This illuminator is wired for two 25-, 40-, or 50-watt lamps and throws a powerful beam of light through two 4-in. clear convex roundels on to the sign beneath. Two red or yellow lenses are used on the front panel. These

lenses serve to attract attention or catch the eye much quicker than the ordinary illuminated sign.

It is dustproof and very rugged and the construction is such that the installation and maintenance is simple. In changing lamps there are no screws to remove, as the lamps become accessible by merely pulling two pins which are fastened to a chain. It is drilled and tapped on each end for ½-in. conduit.

Steel Grating and Tread

A NEW steel grating and tread known as Tri-Lok has been put on the market for the Tri-Lok Company, 5527 Butler Street, Pittsburgh, Pa. There are several distinguishing features to this grating. First, there is a right twist lock in every other bar. Bar *1* in the accompanying illustration shows how this is done. On alternate bars there is a left twist as shown on bar *2* of the accompanying illustration. Into these two reverse twists is forced a third bar, marked *3* in the accompanying illustration, by a 1,600-ton hydraulic press. This action locks the bars together as shown in the lower part of the illustration.

Another interesting feature is that there are no acute angles formed by the bars with the result that there is a maximum of ventilation and light, a total of 90 per cent of the area covered being open. Inasmuch as there are no rivets or bolts the manufacturer states that this grating, therefore, cannot loosen.

Universal Hydraulic Variable Speed Gears

ANNOUNCEMENT is made by the Waterbury Tool Co., Waterbury, Conn., of the application of the Universal hydraulic, variable-speed gear to industrial service. This unit has been in use for a number of years for various purposes in the U. S. Navy. Recently attention has been given to the application of these drives on paper mills and other industrial equipment.

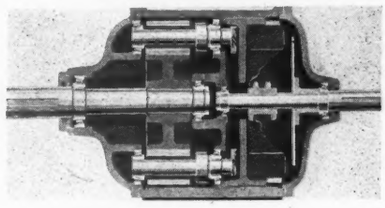
The Universal hydraulic, variable-speed gear, is, according to the manufacturer, a machine for transmitting rotary power at variable speeds and in either direction without stops or abrupt gradations while the source of power rotates continuously in one direction without any necessary change of speed. This source may be an engine, motor, shaft, or other rotating mechanism from which it is desired to transmit power. Oil is used as the medium through which power is transmitted.

The machine, a cross-section of which is shown in the accompanying illustration, consists of two separate units designated respectively as the *A* end and the *B* end. The *A* end is an oil pump operated by the driving power. Its function is to deliver oil to the *B* end at any required pressure and to receive it back again, thus keeping up an oil circulation. The *A* end contains a controlling device by which the quantity of oil delivered to the *B* end is regulated to meet the speed requirements of the *B* end.

The driven shaft, at *A* end, is supposed to rotate continuously in one direction, which may be either right-hand or left-hand. The *B* end is a hydraulic motor with its rotating parts very similar to those of the *A* end. In its capacity as a motor, its shaft rotates at any speed and in either direction in obedience to the quantity and direction of delivery of the oil it receives from the *A* end. The device is made in five sizes with working ratings of 15, 30, 50, 100, and 200 hp.

Variable Speed Reducing Unit

TO MEET the increasing demand for variable-speed drives for conveyors, cement mills, machine tools and other machinery requiring adjustment of speed, William E. Simpson, of Highland Park, Mich., is putting on the market a new line of speed reducers which em-



body, in a single compact unit, a variable-speed drive.

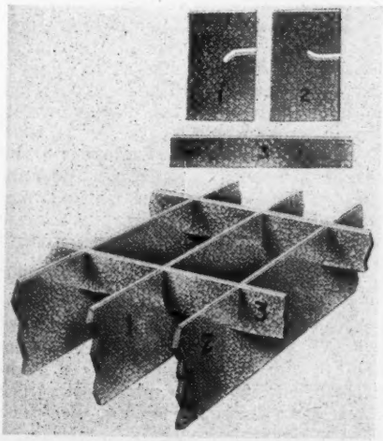
Each unit comprises two reductions only, the first being a modified worm movement with variable ratio, and the second a train of heavy spur gearing adapted to take the heavy torque and shocks of the slow-speed end.

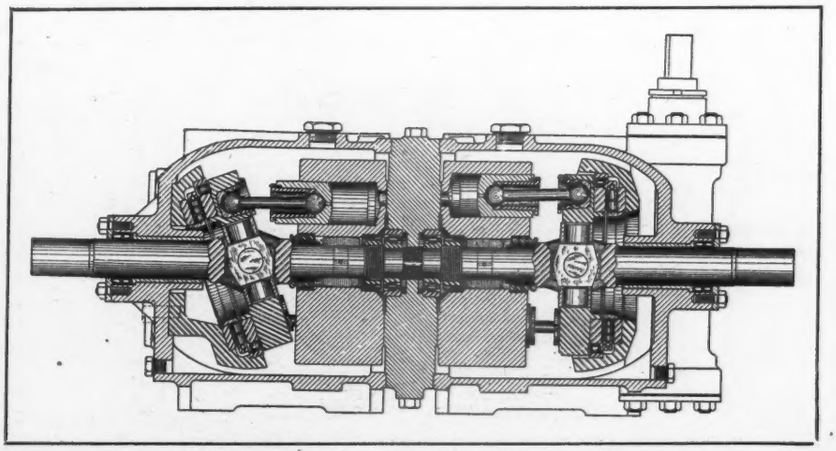
It is stated by the manufacturer that these reducers will operate silently and efficiently at motor speeds up to 3,600 r.p.m. and that the ratio can be readily adjusted from 10:1 to 1,000:1.

Utility "Motor-It" Speed Reducer Unit Drive

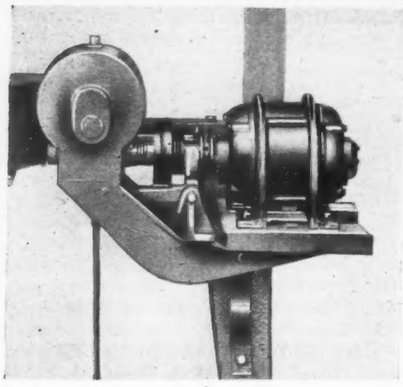
UNIT drives which contain the motor, flexible coupling or clutch, and a speed reducer so designed and mounted as to facilitate their attachment to machines, are being marketed by the Utility Manufacturing Co., Cudahy, Wis., under the trade name of "Motor-It." For continuous operation, a clutch is supplied. For short, intermittent operation a disk clutch, operated by means of a foot lever, is used for connecting the motor to the speed reducer, as is shown in the accompanying illustration. For longer, intermittent operation, an expanding-type clutch is used. An 1,800-r.p.m. motor, clutch and reduction gear are standard equipment. The motor is supplied in ¼-, ½-, ¾-, 1-, 1½-, and 2-hp. sizes.

Reduction gears of any specified ratio may be obtained. Speed reduction is obtained by means of a worm and a wheel or spiral gear. Either roller or ball thrust bearings are used. It is





stated that these units can be applied to any type of machine now driven by means of a belt or gear. The Motor-It unit can be put on the shaft in place of the tight and loose pulley or clutch, as



the unit is bored to fit the customer's shaft. The gear set is completely enclosed and the entire unit is mounted on a cast base.

Variable-Speed Transmission

ANNOUNCEMENT is made of the development and manufacture by the Columbia Vari-Speed Co., 4020 Lake Street, Chicago, Ill., of a new type of mechanical, variable-speed transmission known as the JFS Variable Speed Transmission Unit. It consists of a high-grade roller bearing totally enclosed in a cast-iron housing and running in oil. To obtain a variable ratio of speed between the elements of the bearing, the rollers are given an unusual shape and provision is made for shifting the relative position of the races.

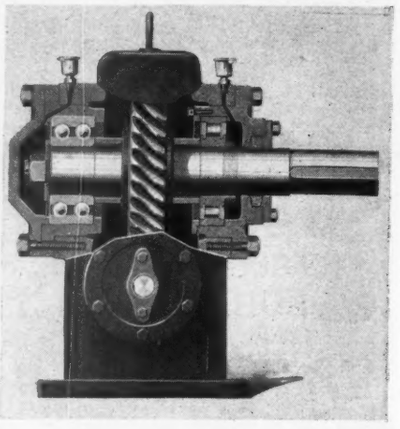
Power is transmitted through this unit by friction between extremely hard metal surfaces bearing against each other under high pressure. The operation as given by the manufacturer is as follows: The vital parts consist of three rollers (designated by *A* in the sectional view in the accompanying illustration) rolling around the outside of the two inner races *D*, and around the inside of the two outer races *B* and *C*. The inner races are rotated by the input shaft *S*, while the outer races are held from rotating. The rollers are, therefore, caused to move in planetary fashion around the axis of the machine, and at a slower speed than that of the inner races. Each roller is mounted in a yoke *G* which in turn is mounted on the spindle *M*. The spindle is thus pulled around by the rollers and rotates the output shaft *R* to which it is keyed. The number of revolutions which the input races must make to cause the rollers to make one complete circuit depends on where the points of contact occur between the rollers and races. These may be shifted at will by rotating the handwheel, which varies the ratio of speed between the input and output shafts. Lubrication of moving parts is obtained by a splash system.

This unit is manufactured in two types. Type *R* variable-speed transmission gives a minimum speed reduction of 9:1 with a maximum variation of 5:1. For example, if the unit is connected to an 1,800-r.p.m. motor, the output shaft will have a maximum speed of 1,000 r.p.m., and a minimum speed of 200 r.p.m., and any speed ratio desired between these limits. Where a greater average reduction is desirable, the Type *RG* unit is used, which has a 5:1 planetary gear built into the output end of the unit. This gives an additional reduction of 5:1, so that if driven by an 1,800-r.p.m. motor, the range of output speeds would be from 200 r.p.m. down to 40 r.p.m. These units are manufactured in capacities up to 7½ hp. at present.

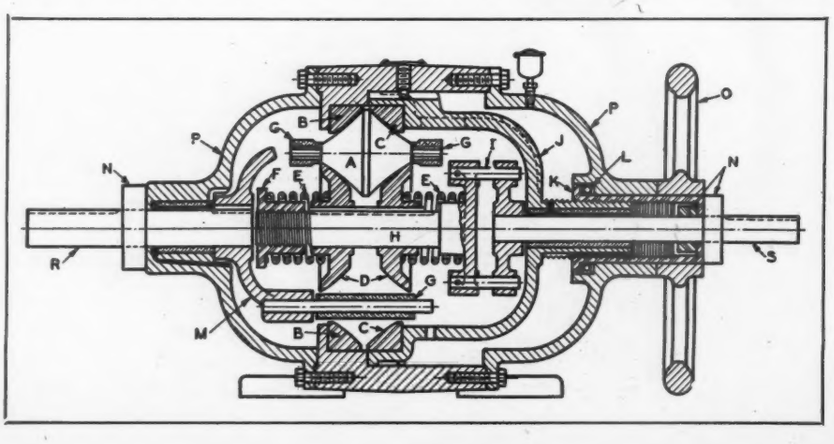
It is stated that the construction is such that units which have been in operation for a considerable length of time show no evidence of wear on the races or rollers, due to the fact that an especially hard metal is used for these. The output shaft may be direct-connected to the machine and driven by the use of a flexible coupling or through a belt, chain, or gear drive. In the latter cases an outboard bearing is furnished with the reducer. If the unit is mounted overhead where it is not convenient to get at the control wheel, it may be placed at any desired point and connected to the unit by a chain and sprocket.

Worm Gear Speed Reducer

ANNOUNCEMENT is made by the Philadelphia Gear Works, Richmond and Tioga Sts., Philadelphia, Pa., of the marketing of the Type AX worm gear speed reducer shown in the accompanying illustration. The construction, as described by the manufacturer, is as follows: The worm is made from low-carbon, nickel-alloy steel forged integral with its shaft. The worm threads are hardened and ground and the worm shaft is mounted on ball bearings for taking thrust in both directions, as well as radial loads. The worm gear is made of steel cast bronze shrunk and securely fastened to cast iron spider. The worm



wheel shaft is made of nickel-alloy steel, heat-treated and ground, and the no-load end is mounted on a double-row ball bearing for taking thrust in both directions. The load end of the worm wheel shaft is mounted on a Norma Hoffman roller bearing which is designed to compensate for overhung loads such as pinion, pulley, or sprocket drive, thus eliminating the necessity of providing an extension on the worm wheel shaft for an outboard bearing support.



Manufacturers of Power Transmission Equipment Form Association

THE Survey Committee appointed at a meeting of belting, transmission and accessory manufacturers, held in Cleveland on June 10th, met at the Old Colony Club, Waldorf-Astoria, New York, on September 14th with practically a full committee present. Reports of the Chairman and Secretary indicating a great deal of interest in the proposed movement were submitted, and the matter of further procedure was taken up in considerable detail.

As the result of considerable investigation by the Chairman and Secretary, suggestions were made to the Committee that instead of the preliminary survey that was to be made in accordance with the decision reached at the Cleveland meeting, it would be better to lay the groundwork at this time for an Association, making at the same time a survey which would determine the procedure to be followed upon the final organization of the Association, and then when such an organization is formed, to establish a Research Bureau and proceed along the lines laid down by the Organization Committee.

The matter of securing additional memberships was thoroughly discussed and the Organization Committee decided to constitute themselves a committee of the whole on membership, the secretary to furnish each member with a list of logical prospects in his terri-

tory. In this way everyone interested in such a movement, would be approached and informed fully as to the objects and purposes of the Association.

The Chairman was instructed by the full committee present, to appoint a sub-committee to report to the full committee on a name and outline the objects of the Association. The following members were appointed on this committee:

Geo. H. Fisher, Pres. Fisher Leather Belting Co., Philadelphia, Pa., chairman; Edward H. Ball, Pres. Chicago Belting Company, Chicago, Ill.; Wylie K. Lee, Pres. Clipper Belt Lacer Company, Grand Rapids, Mich.; F. E. Barth, Genl. Sales Mgr. Graton & Knight Mfg. Co., Worcester, Mass.; C. M. Murray, Pres. Transmission Ball Bearing Co., Buffalo, N. Y.; W. H. Fisher, Secy. and Sales Mgr. T. B. Wood's Sons Co., Chambersburg, Penna., Ex officio; W. W. French, Sales Promotion Manager Dodge Manufacturing Corp'n, Mishawaka, Ind., Ex officio.

This committee reported very favorably on the name, "Power Transmission Association," which was adopted.

The objects of the Association are: To promote the most efficient and economical distribution of power; to make a scientific study of all engineering problems connected with the transmission of power; to accumulate and compile accurate and authoritative information regarding the most economical and efficient power transmission methods and to place this information at the disposal of all power users through the members of this organization and through planned publicity; and to further the interests of affiliated manufacturers and their distributors making and handling power equipment.

The committee considered several propositions submitted to it bearing on the subject of making the survey, and it was decided to work this out further for submission at a general meeting, which was tentatively set for November, the exact date to be decided upon and announced later.

An aggressive attempt is being made to add many more firms to the list of about 80, who have contributed to the Association work up to the present time. The list of members is as follows:

T. B. Wood's Sons Co.; Medart Company; Moloney Belting Co.; Hans Rees' Sons; Page Belting Co.; E. F. Houghton & Co.; Rockwood Mfg. Co.; U. S. Leather Co.; Alexander Brothers; I. B. Williams & Sons; Graton & Knight Mfg. Co.; Clipper Belt Lacer Co.; American Pulley Co.; Bond Foundry & Machine Co; Royersford Foundry & Machine Co.; A. & F. Brown Co.; Security Rubber & Belting Co.; Chas. Bond Co.; Valley Iron Works; Standard Pressed Steel Co.; F. Raniville Co.; Shingle-Gibb Leather Co.; Transmission Ball Bearing Co; O'Meara Belting Co.; Meier-Andress Belting Co.; Ohio Valley Pulley Works; Fensholt & Fechner Co.; Baltimore Belting Co.; Bonner & Barnewell, Inc.; Chicago Belting Co.; Pyott Foundry Co.; Bay State Belting Co.; Kistler, Lesh & Co.; Cling-Surface Co; Schwartz Belting Co.; L. P. Degan Belting Co.; H. N. Cook Belting Co.; Holyoke Belting Co.; Chicago Pulley & Shafting Co.; J. A. Webb Belting Co.; Whiting Leather & Belting Co.; McAdoo & Allen; E. P. Alexander & Son; Fisher Leather Belting Co.; Plant Co.; Brown Clutch Co.; W. H. Salisbury & Co., Inc.; McLeod Leather & Belting Co.; Eagle Belting Co.; Eclipse Wood Pulley Co.; McCauley Belting Co.; Saginaw Mfg. Co.; California Belting & Supply Co.; Klinger-Dills Co.; Baldwin Belting & Leather Co.; Chicago Rawhide Mfg. Co.; Detroit Belt Lacer Co.; Bickford & Francis Belting Co.; Byrnes Belting Co.; Grand Rapids Belting Co.; Hide Leather & Belting Co.; Hudson Belting Co.; Chas. L. Ireson, Inc.; Jewell Belting Co.; Johnson Leather Belting Co.; Edward R. Ladew Co., Inc.; Laurence Belting Co.; Missouri Belting Co.; New York Leather Belting Co.; Norwich Belt Mfg. Co.; N. Palmer & Co.; Geo. Rahmann & Co.; J. E. Rhoades & Sons; Chas. A. Schieren Co.; Schwartz Belting Co.; Schultz Belting Co.; Union Belt Co.; Hyatt Roller Bearing Co.; Bay Belting & Supply Co.; Sawyer Leather Belting Co.

Owing to the fact that funds solicited by the committee in the first instance were for the definite purpose of making a survey, it was decided that a complete explanation of the purposes of the Association and the new measures proposed by the committee, would be sent out to the membership at once and their permission asked to follow the new course of procedure, rather than the one first decided upon.

Much enthusiasm was manifested over the work so far accomplished and W. H. Fisher, the Chairman, pointed out that with the membership already enrolled, plus the members of the Leather Belting Exchange, who have endorsed the movement and decided to go in as a body, the membership would be about 100; this, however, is not considered enough to insure the success of the Association in the rather extensive program mapped out, and the Committee will undertake to increase this number further before the general meeting, to which all those interested in the movement and who have contributed, will be invited.

Trade Literature

you should know about

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Dead-Ending Clamp—Bulletin 101 describes screw-jack dead-ending clamps for stranded cable and illustrates a number of installations. — The Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

Belt-Slacker — Helpful data to the engineer on the application and installation of this device on short center belt drives is given in leaflet Form B-28.—Harry M. Perry, 702 Main St., Los Angeles, Cal.

Leather V-Belt Drives—A circular shows the principles involved in Graton & Knight leather V-belt drives, and also illustrates various applications of such belts made by this company.—Graton & Knight Co., 356 Franklin St., Worcester, Mass.

Speed Reducers—A new catalogue describes the complete line of Philadelphia worm gear herringbone and spiral bevel herringbone speed reducers in any ratio for giving straight-line, right-angle, or vertical drives.—Philadelphia Gear Works, Richmond and Tioga Sts., Philadelphia, Pa.

Portable Elevator — Bulletin 90F shows how the portable elevators can be mounted and used for stationary work.—Revolvator Co., 336 Garfield Ave., Jersey City, N. J.

Speed Transformer—Bulletin 105 describes the Poole type H speed transformer. Bulletin 106 describes and illustrates the Poole type K speed transformer.—Poole Engineering & Machine Co., Baltimore, Md.

Flexible Coupling—Bulletin 107 illustrates and describes the various types of Poole flexible couplings, which can be used for continuous or reversing service at high or low speeds. Bulletin 108 describes in detail the various parts of the Poole flexible couplings.—Poole Engineering & Machine Co., Baltimore, Md.

Grease—A 28-page booklet entitled, "Densities and Uses of Keystone Grease," contains an application chart which gives a partial list of machinery lubricated with Keystone grease and indicates the methods of application as well as the recommended densities.—Keystone Lubricating Co., Philadelphia.

Lubricator—An 8-page booklet describes the Knorr lubricator, which is designed to feed grease automatically to the shaft while it is in motion.—Knorr Lubricator Sales Co. of New England, 80 Federal St., Boston, Mass.

Belt Dressing—A 16-page booklet entitled, "The Proper Care of Belts," discusses belts and their care, and describes the various Dixon belt dressings, with their application.—Joseph Dixon Crucible Co., Jersey City, N. J.

Carbon Products—Catalog B-4 is a 40-page, loose-leaf, pocket-size catalog of carbon brushes, and contains a description of each type and listing of sizes, together with directions for ordering brushes.—The United States Graphite Co., Saginaw, Mich.

Arc Welding Unit—Bulletin GEA-9 describes the gas-engine-driven type of arc welding units and Bulletin GEA-255, the stationary or portable, belt- or motor-driven arc welding units.—General Electric Co., Schenectady, N. Y.

Power Drive Data—An attractive, leather-bound booklet, vest pocket size, entitled "Guide Book of Drives," has just been published by the Link-Belt Co. This little volume gives a description of chain drives in general; chains compared with belts; the use of low- and medium-speed drives; roller chain drives; silent chain drives, including tables for use in ordering chains from 1- to 1,000-hp. rating at high speed; gear drives; belt drives; and simple arrangements for compound drives.—Link-Belt Co., 910 S. Michigan Ave., Chicago, Ill.

Drop Light—A folder describes the Triplex adjustable roller drop light and the Triplex drop extension light.—I. T. Gray & Co., 522 Fifth Avenue, New York, N. Y.

Portable Electric Drills—A new catalogue describes the various sizes and types of Wodack portable electric drills. —Wodack Electric Tool Corp., 23 So. Jefferson St., Chicago, Ill.

Micarta—A 24-page booklet, entitled "A Material of Endless Possibilities," contains information about this material and the many uses to which it has been put and indicates the possibilities for other applications.—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

New Substation—Bulletin 2056 describes and shows the layout of the new Pittsburgh Transformer Company's substation at their Manchester plant.—Pittsburgh Transformer Co., Pittsburgh, Pa.

Welding and Cutting Equipment—A 32-page, pocket-size junior catalog illustrates, describes briefly, and prices the various welding and cutting equipment manufactured by this company.—Smith Welding Equipment Corp., 2619 Fourth St., S. E., Minneapolis, Minn.

Heating Units—Bulletin C-106 illustrates and describes Chromalox heating units, and gives tables useful in their application. Booklet C-105 shows many applications where Chromalox heating units can be used.—Edwin L. Wiegand Co., 422 First Ave., Pittsburgh, Pa.

Power Transmitting Appliances—Catalog 4 lists, describes, and prices the various hangers, bearings, countershafting supplies and other equipment manufactured by this company.—Standard Pressed Steel Co., Jenkintown, Pa.

Oil Purification—A circular describes the De Laval method of purifying transformer and switch oil, and shows views of various installations of purifying equipment.—The De Laval Separator Co., 165 Broadway, New York, N. Y.

Portable Saw Table—A folder illustrates and gives the advantages claimed for the new portable table-mounted Wonder Saw which is designed for either electric or gasoline motor drive. —St. Louis Machine Tool Co., 1429 Pine St., St. Louis, Mo.

Gas Welding and Cutting Apparatus—Catalog 40 illustrates, describes, and prices the wide range of welding and cutting torches, attachments and regulating equipment manufactured by this company. — The Bastian-Blessing Co., 240 E. Ontario St., Chicago, Ill.

Push Button Magnet Controller—A folder illustrates, describes, and gives the advantages claimed for the Ohio magnet controller and master switch for use in connection with the rapid operation of electromagnets. A limited reverse current applied automatically, it is stated, causes the magnetism to drop to zero and the load to drop promptly.—The Ohio Electric & Controller Co., 5900 Maurice Ave., Cleveland, Ohio.

Air Hoists—A 16-page booklet illustrates a large number of applications of the Turbinair portable hoists of 1-ton capacity.—Sullivan Machinery Co., 122 S. Michigan Ave., Chicago, Ill.

Cast-Iron Pulleys—A circular describes the qualities claimed for Pyott Red Face cast-iron pulleys and flywheels.—Pyott Foundry Co., 328 N. Sangamon St., Chicago, Ill.

Copper Covered Wire—A folder gives engineering data and wire tables on the use of Copperweld non-rusting guy, messenger, and span wire.—Copperweld Steel Co., Braddock P. O., Rankin, Pa.

Motor and Wire Data—A celluloid pocket card gives the ampere ratings of a.c. and d.c. motors at full load and also the allowable carrying capacities of wire.—Monitor Controller Co., Baltimore, Md.

Transformer Data—No. 8 of a series of data sheets discusses, "How to Determine the Proper Marking of Three-Phase Transformers," with special reference to Moloney transformers.—Moloney Electric Co., St. Louis, Mo.

Aluminum Paint—A booklet entitled, "Bitulumin," discusses aluminum paints and metal primers in the form of 77 technical questions with their non-technical answers.—Hill, Hubbell & Co., San Francisco, Calif.

Variable Speed Blower—Bulletin 36 contains numerous examples of installations of Wing Type EM variable-speed blowers for connection to heating equipment.—L. J. Wing Mfg. Co., 352-362 13th St., New York, N. Y.

Traveling Cranes—Bulletin 176 gives the standard building clearances for Whiting overhead electric traveling cranes.—Whiting Corp., Harvey, Ill.

Motors—New price lists give descriptive information and prices on Type RS repulsion-start, induction, single-phase motors and Type SC squirrel-cage induction polyphase motors.—Century Electric Co., 1806 Pine St., St. Louis, Mo.

Concrete Floor Treatment — Folder No. 1 contains a complete description and detailed specifications of treatments for hardening, dustproofing, and waterproofing concrete floors. These specifications are in loose-leaf form, mounted in a binder. The general index covers integral hardeners, surface hardeners, concrete coatings, concrete accelerators, and freeze-proofers. — The Master-Builders Co., Cleveland, Ohio.

Molybdenum Ball Bearings — An 8-page folder entitled "Molybdenum Means More Life in 'Em," discusses the development and use of molybdenum steel for SRB forged balls in single- and double-row angular ball bearings. —Standard Steel & Bearings Co., Inc., Plainville, Conn.

Mechanical Rubber Goods—A series of booklets bound in a loose-leaf folder describe Goodrich rubber belting, transmission belting, conveyor belting, air and other hose and other mechanical rubber products and give applications and operating data.—The B. F. Goodrich Rubber Co., Akron, Ohio.

Starting Switch—Bulletin 105 describes the Clark starting switch which is designed to start and stop small induction motors that require a full load current of 3½ amp. or more.—The Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

Hand Truck—A 20-page, pocket-size catalog describes and illustrates the line of two-wheel pressed-steel hand trucks which are made up in nine different styles in 25 sizes, covering the ordinary hand truck requirements.—The American Pulley Co., 4200 Wissahickon Ave., Philadelphia, Pa.

Porcelain Insulators—A monthly publication entitled, "Thomas Topics," is devoted to descriptions of various Thomas porcelain, insulating products and other interesting information.—The R. Thomas & Sons Co., East Liverpool, Ohio.

Centrifugal Drive—Circular GEA-302 illustrates, describes and gives the operating characteristics of the G-E vertical, variable-voltage, direct-connected, squirrel-cage motor for centrifugal drives.—General Electric Co., Schenectady, N. Y.

Texrope Drive—Bulletin 1228-D describes the application and shows illustrations of a number of applications of the Allis Texrope drive, which consists of a textile base, multiple belt, operating in grooved sheaves for close-center drive.—Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Power Transmitting Appliances — Catalog G contains 288 pages and covers the complete line of power-transmitting appliances, ball and roller bearings, conveying and elevating machinery, and miscellaneous factory equipment manufactured and distributed by this company.—Chicago Pulley & Shafting Co., 17-23 N. Desplaines St., Chicago, Ill.

Safety Switches—A monthly house organ entitled, "Trumbull Cheer," describes Trumbull equipment and up-to-date installations, and contains other interesting information.—The Trumbull Electric Mfg. Co., Plainville, Conn.

Condulet Branch Extensions—Bulletin 2087 describes the OCB Condulet Branch Extensions which provide a means for making extensions to existing conduit installations by bridging from one condulet to another through the cover opening, thereby making it unnecessary to alter or cut into the existing conduit line. — Crouse-Hinds Co., Syracuse, N. Y.

Power Transmission Equipment — Catalog 26, which is printed in three sections, covers the line of power transmission equipment manufactured by this company. Section A is on flexible couplings; section B covers the application of clutch pulleys, cut-off couplings, and related equipment; section C covers rope drives, gears, speed transformers, and contains a large amount of useful engineering information. — The Hill Clutch Machine & Foundry Co., Northeast Corner Breakwater Ave. & West 55th St., Cleveland, Ohio.